POWER PLANT ENGINEERING

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New Waukegan Plant Handles Increased Load

PLANT NO. 6 OF THE PUBLIC SERVICE CO. OF NORTHERN ILLINOIS UTILIZES SUPERHEATERS, ECONOMIZERS AND STAGE FEED WATER HEATERS

TO COPE with the rapidly increasing demand for power in the districts which it serves, the Public Service Co. of Northern Illinois has recently put into service the first unit of its new plant at Waukegan, Ill., which is ultimately to have a capacity of at least 250,000 kw. Located, as it is, on the lake front immediately adjacent to the northern boundary of the city of Waukegan and within half a mile of two railroad systems, the plant is ideally situated as regards cooling water and fuel transportation.

Although construction was started at as late a date as August, 1922, the first unit was put up on the line after an elapsed time of less than 14 months, in October of this year, which is something of an achievement in the way of construction progress. This speed was made necessary by the greatly increased current demands in this district. In its present state of completion the plant comprises three boilers of 1409 hp. each and one turbine of 25,000 kw. capacity, with all the auxiliary equipment required for the operation of these units. The present building is designed to house six boilers and two generating units; further enlargement will require extension to the building. There are to be three boilers on each side of the firing aisle, which is at right angles to the length of the turbine room and approximately on the same level. The boiler room floor is 29 ft. above the ash track, at grade, which arrangement provides ample room to permit ash to be removed directly in standard cars.

DOUBLE-DECK BOILERS ARE USED

Boilers are of the horizontal tube, inclined header, double-deck, cross-drum type, as shown in Fig. 2, built by Babcock & Wilcox. Each has a total heating surface of 14,086 sq. ft., distributed in 8 rows of 3¼-in. tubes in the lower deck and 17 rows of 2-in. tubes in the upper deck. The boilers were designed for a pressure of 400 lb. per sq. in. gage, and a total steam temperature of approximately 700 deg. F. The superheater, which also was furnished by Babcock total heating surface of 2286 sq. ft.

Soot is removed from the heating surfaces periodically

at intervals of about 10 hr. by means of a system of 22 soot blowers.

Gases of combustion pass through the setting practically without interruption. The lower tier of tubes is totally devoid of baffles. The entire length of the tubes is exposed directly to the fire, i. e., the whole lower deck constitutes the first pass in the boiler. After passing through this section, the gases traverse the superheater elements and then the second boiler pass or the first pass of the upper deck. In this tier there is one vertical baffle which divides it into two passes, the first or forward pass having about twice the heating surface of the second. The gases pass downward through the last pass and then through the vertical circulating tubes to the economizer section. From this point the flue gas is handled by the induced draft fan.

To permit of ample gradation in the amount of air supplied for combustion to meet the varying requirements and varying resistance to air-flow of the fuel in its passage through the furnace, each unit is equipped with five wind boxes in which the under-grate pressure may be varied at will by hand manipulation of suitable division dampers.

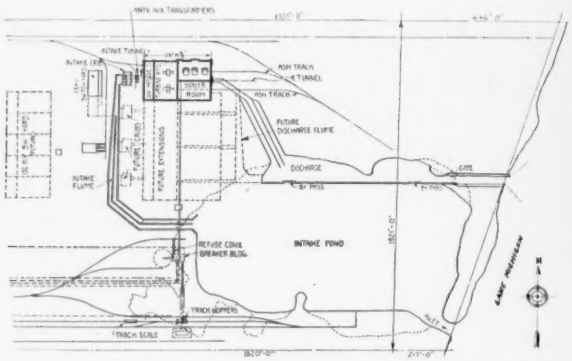

FIG. 1. PLANT OCCUPIES A 90-ACRE SITE ON THE SHORE OF LAKE MICHIGAN

To insure that combustion be completed before the furnace gases come in contact with the boiler heating surface an average distance of 16 ft., 8 in. is provided between the grate and the bottom of the first row of tubes. The resulting furnace volume amounts to 4300 cu. ft. or about 3.05 cu. ft. per b.hp. at rating.

B. & W. forced-draft chain grate stokers are used, driven by a 10-hp. variable speed alternating current motor, through a system of reduction gearing. This is, as far as is known, the first chain grate stoker installation driven by an a. c. motor. Each stoker is 21 ft. wide and 18 ft. 3 in. long and has an active surface of 383 sq. ft. The ratio of heating surface to grate area is thus 11,086 to 383, or approximately 37 to 1.

Air for combustion is supplied by a combination of forced and induced draft fans, each boiler having one fan of each type. The forced-draft fans each have a capacity of 60,000 cu. ft. per min. at standard temperature and the induced fans have a capacity of 92,000 cu. ft. per min. at 350 deg. F.

These blowers are driven by direct connected 440-v. variable speed a. c. motors. The forced-draft fans are each driven by a 75 hp. motor and the induced fans by a 150 hp. motor. Flue gases are removed through a brick-lined self-supporting steel stack about 150 ft. high from the boiler room floor and 15 ft. inside diameter at the top. This stack is supported on the steel girders of the building framework.

It will be noted that the cross sectional drawing of the boiler room indicates an air preheater in the uptake connection. It is possible that at some future date such heaters will be installed but at the present time the plant equipment does not include this item. As installed, the forced-draft fan takes air directly from the boiler room and delivers it under pressure to the forced-draft duct from which it is distributed as conditions require to the five wind boxes under the stoker.

In accord with the best combustion practice, an effort is made to maintain practically balanced draft conditions. That is to say, the speed of the forced-draft and induced-

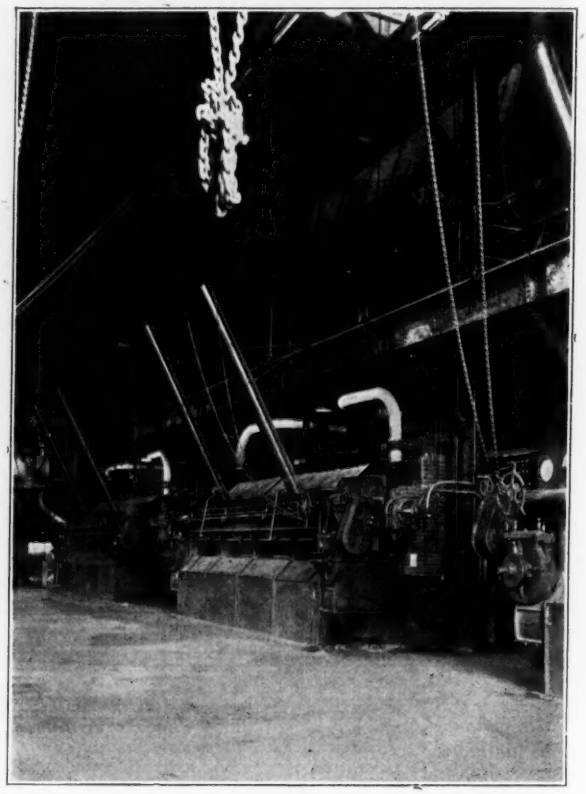

FIG. 2. THREE 1408-HP. BOILERS ARE INSTALLED

draft fans are so adjusted in relation to each other and in relation to the resistance to air-flow through the grate on the one hand, and through the boiler and economizer on the other, that the draft over the fire is kept at a constant low value. Control of the speed of both fans as well as that of the stoker and the position of the wind box and uptake dampers is effected by manual operation.

To enable the operating crew to maintain the set standard of combustion efficiency and to keep track of the boiler performance several types of gages and indicators are installed where they may be conveniently observed from a point near the front of the boilers. Besides the two indicating pressure gages on the boiler front there is an indicating and recording combination steam and air-flow meter connected into each boiler lead, and across the boiler setting. At the rear of the boiler there is a venturi feed water meter

which may be checked against the measurement of steam flow.

Indicating thermometers are installed to show the flue gas inlet and outlet temperatures. Similar provision is made also for indicating the total steam temperature.

Feed Water Heaters

Condensate from the main turbine unit is heated in two stages in two closed type feed water heaters. The low pressure heater is supplied with steam at about 4 lb. absolute extracted from the low pressure stage of the turbine and the high is supplied at atmospheric pressure with steam extracted from an intermediate stage of the turbine. From

It may be of interest to note here the relative proportions of the various heating surfaces, i. e., the boiler heating surface, the economizer surface and the superheater surface. The quantities, for one boiler unit, are respectively, 14,086, 8837, and 2286 sq. ft. The ratio of one to the other is approximately 6.15 to 3.86 to 1 in the order named. Expressed as per cent of the boiler heating surface the economizer surface is 63 per cent and the superheater surface, about 16 per cent.

Under present operating conditions from 2 to 3 per cent make up water is required. The water is taken from the condenser circulating system and is passed through sand filters and a zeolite feed water treating system to re-

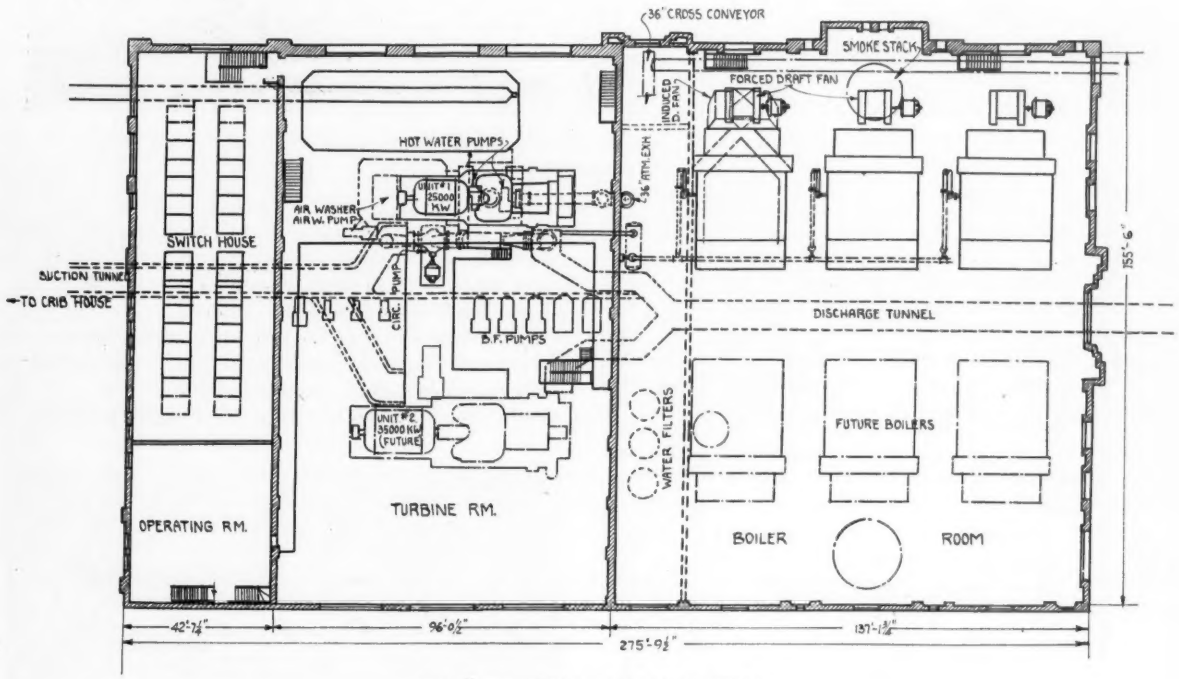

FIG. 3. GENERAL PLAN OF STATION

these heaters the water is delivered to a feed water storage tank.

Float valves in this tank control the make-up supply. There are three of these float controls, located at different levels. The first or upper float acts to admit water from the hot water storage reservoir to which all drips and drains are piped. From this reservoir the water is pumped through a third closed heater to the feed water tank. This heater is supplied with exhaust steam from the steam driven plant auxiliaries.

When the level in the feed water tank falls below the range of the first float a second float controlled valve functions to admit water from the hot water reservoir to the hot well of the main condenser under a vacuum. Further lowering of the water level in the feed water tank actuates a third float controlled valve to admit cold service water direct to the tank.

From this tank the feed water pumps deliver the water to the economizers, which are located in the uptake immediately behind the boilers and which have a total heating surface of 8837 sq. ft. or about 63 per cent of the boiler heating surface.

move the greater portion of the scale-forming material. After this treatment the make-up is introduced into the hot water reservoir.

Most of the auxiliaries in the plant are equipped with motor drive as it is desired to provide steam for feed water heating by bleeding the main turbine rather than by using steam-driven auxiliaries unless they are required on the score of reliability of operation.

Power for these motors is obtained from a station bus which is supplied through auxiliary transformers from the main bus. No house turbine is used.

Three boiler feed pumps are provided which supply water to the economizers under a head of 460 lb. per sq. in. These pumps are 5-stage centrifugal units and have a capacity of 500 g.p.m. each. The units are mounted together in a battery on the condenser room floor as shown in Fig. 6. Two are driven by direct connected 250-hp., 2275 r.p.m. turbines and one by a direct connected 350-hp., 1750 r.p.m. induction motor.

To insure that the water level in the boilers be properly maintained, the boilers are equipped with feed water regulators and the feed pumps, with pump governors.

Coal and Ash Handling Equipment

Illinois run-of-mine coal having a heating value of approximately 11,000 b.t.u. per lb. is used. It is brought in by rail and either delivered directly to the breakers or piled in the storage yard for future use. Coal is conveyed from the track hopper by a shaking feeder to a belt conveyor which delivers it to the breaker house. Here miscellaneous foreign material is separated out and the coal is broken down to the correct size for the stokers. From the Bradford breaker it is delivered to a system of 24-in. belt conveyors working in the long overhead runway shown in Fig. 4, which feeds into a cross conveyor which in turn distributes the coal uniformly in the boiler house bunkers by means of an automatic traveling tripper. From the bunkers the coal is dropped through down-spouts to the individual stoker hoppers. The handling to and from storage piles in the yard is accomplished by means of two 20-T. locomotive cranes having a capacity of 140 T. of coal per hr. The capacity of the belt conveying system is also 140 T. per hr.

The layout of the plant property calls for an ultimate storage capacity of from 250,000 to 300,000 T. which at the ultimate capacity of the plant is sufficient storage for about 45 days. To meet present requirements a storage of 11,000 T. is carried in the yards.

As installed, the boiler room bunker has a capacity of 175 T. per boiler, or a total of 1050 T. for the six boilers that are ultimately to be supplied from it. The coal is weighed as received on track scales in the yard and again weighed by a weightometer on a conveyor from the breaker house to the boiler room. To handle the coal used a total of 2565 ft. of conveyor belting is used and 105 hp. of motors are required to drive the apparatus. Power requirements of the breaker amount to 125 hp.

Ash is deposited over the end of the grate into a 50-T. ash hopper from which it is dropped into standard gondola cars that may be run in on a track directly below. At the present time this ash is used for filling-in purposes to build up some of the low land including the company's property.

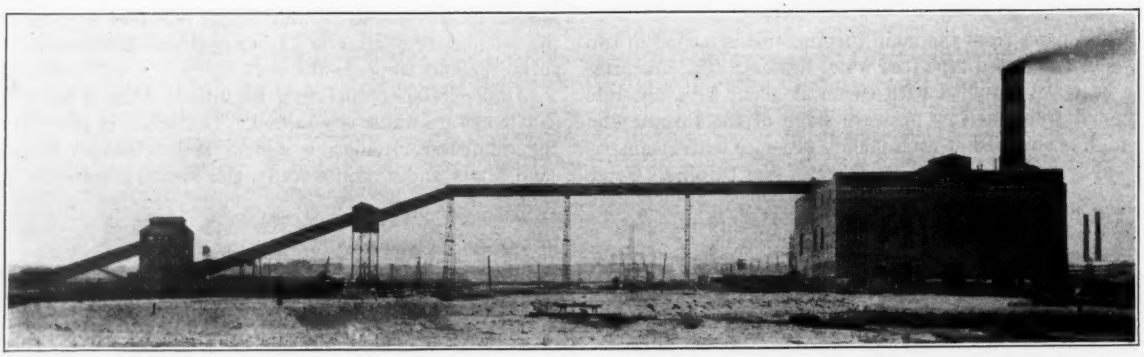

FIG. 4. GENERAL VIEW OF PLANT SHOWING COAL HANDLING SYSTEM AND SPACE AVAILABLE FOR FUTURE INSTALLATIONS

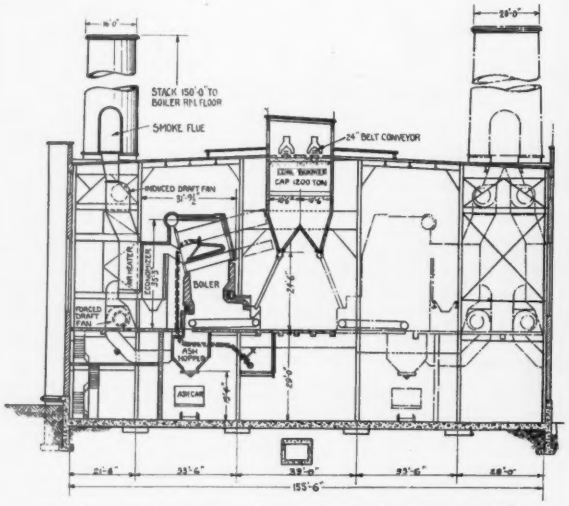

FIG. 5. CROSS SECTION OF PRESENT BOILER ROOM

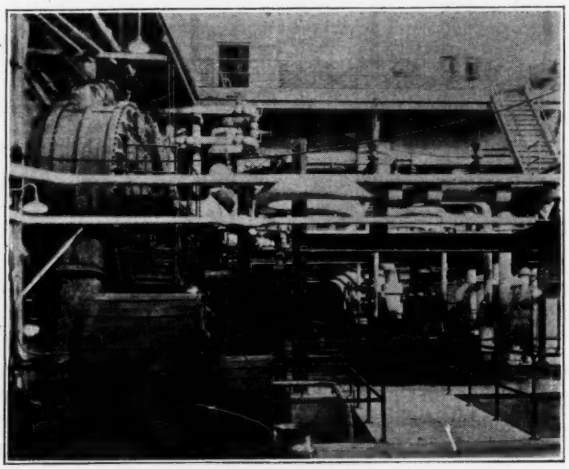

FIG. 6. CONDENSER AND AUXILIARY EQUIPMENT IN TURBINE ROOM BASEMENT

Prime Mover is Arranged to Facilitate Supervision

From an examination of the layout of the turbine room it would seem that one of the chief considerations in the mind of the designer was to have all the equipment visible to the operator from a given point in the room. The turbine room is one large open space from the ground level to the roof, extending the entire length of the building.

The interior decoration of this room is such as to meet with the favor of the most fastidious or most aesthetic. As well as being pleasing to the eye it serves to give the room a maximum of natural illumination. The walls are of white tile paneled with green in a simple and artistic manner. The north wall is almost entirely occupied by series of windows running practically the whole height of the building and arched over at the top.

At a point just below the level of the boiler room floor a narrow balcony extends around all sides. It is on this level that the prime movers are located, the concrete foundation being built up to this point around the condenser. The auxiliary equipment is grouped about on the ground floor in such a way as to afford a maximum convenience to the operating crew. All of this equipment is readily visible from the operating room on the west balcony and is accessible to the overhead crane.

The first turbo-generator unit installed, shown in the headpiece is an Allis-Chalmers, Parsons type single cylinder reaction turbine direct connected to the generator. It is designed to take steam at 350 lb. pressure and 240 deg. F. superheat, and exhaust into a vacuum of about 1 in. absolute. The unit operates at 1800 r.p.m. and generates 3-phase, 60-cycle current at 12,000 v. At rating the unit has a capacity of 25,000 kw. at 90 per cent power factor, that is, 27,777 kv.a. Excitation for the generator is supplied by a direct connected 200-kw., 250-v. exciter. Ultimately this station will tie in with the rest of the system through a 132,000-v. transmission line. For the purpose of keeping the generator temperature down to the value designated for continuous rated capacity, an open, air circulating system is provided which is capable of handling 75,000 cu. ft. of air per min. The system is equipped with an air washer which serves the double purpose of removing all dust from the air and reducing the temperature to approximately that of the circulating water available.

Condenser Equipment

Vacuum is maintained on the turbine by an Allis-Chalmers horizontal two-pass cylindrical condenser having a total cooling surface of 32,000 sq. ft. This unit is attached rigidly to the exhaust port of the turbine and rests on adjustable spring supports which serve to take up any stress occasioned by expansion and contraction. The tubes are 1 in. outside diameter No. 18 B. W. G. and are made of a composition 70 per cent copper and 30 per cent zinc. One Allis-Chalmers 36-in. horizontal centrifugal circulating pump supplies the cooling water for the condenser. It is direct connected to and driven by a 300-hp. two-speed induction motor which may be operated at 390 and at 435 r.p.m. The maximum capacity of the pump is 35,000 g.p.m. which is sufficient to condense all the exhaust from the turbine during the season when the circulating water is at its maximum temperature.

Condensate from the condenser is handled by two Allis-Chalmers two-stage, condensate pumps having a capacity of 600 g.p.m. each. Each is driven by a 50-hp. constant speed induction motor.

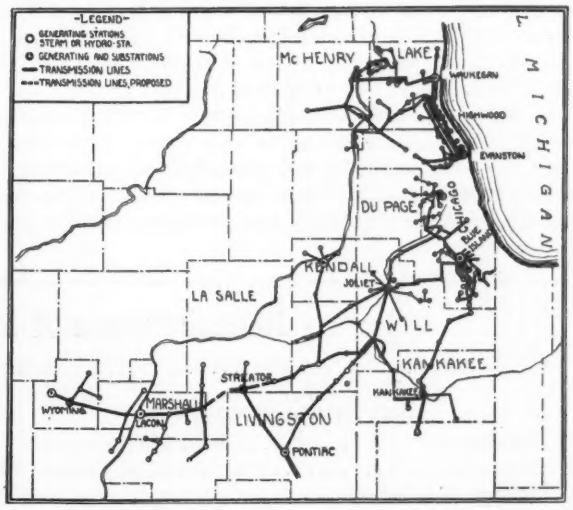

FIG. 8. TERRITORY SERVED BY THE COMPANY

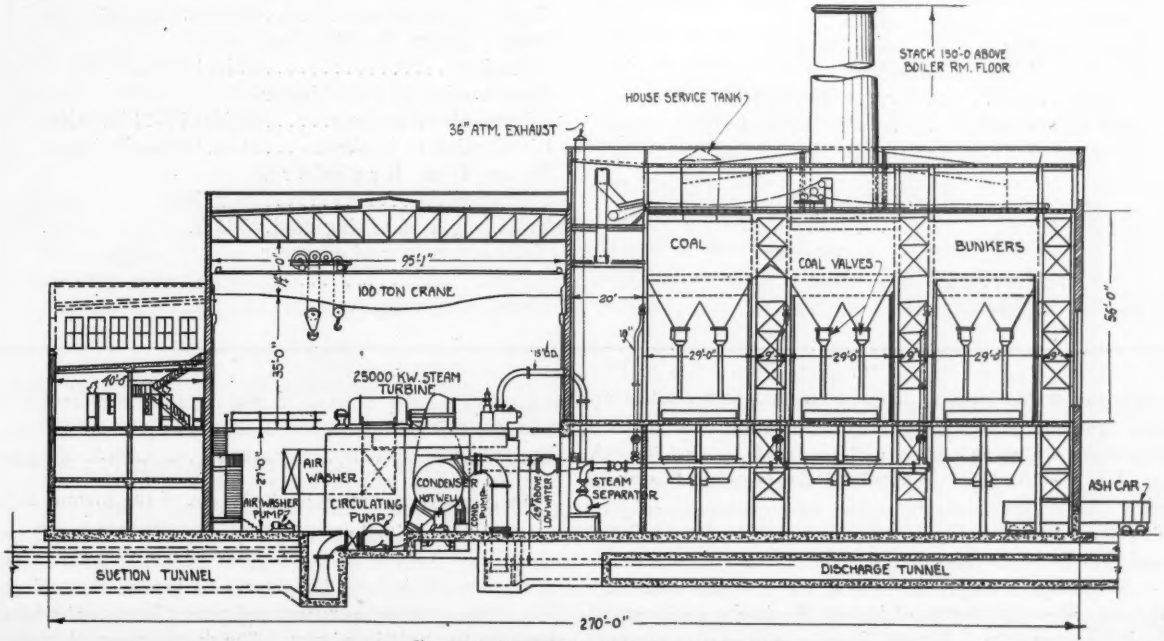

FIG. 7. LONGITUDINAL SECTION OF PLANT

Air and other non-condensable gases that might be present in the condenser are removed by two two-stage evacator steam jets having a capacity, each, of 30 cu. ft. of free air per min. at 1 in. absolute.

Inasmuch as the circulating water is taken directly from the lake the temperature is comparatively low. During the winter months it will probably average not much above about 40 deg. F. There are, however, times in the summer when the circulating water temperature will reach probably 75 deg., although the average will be below 70 deg. During these periods when warm water only is available the circulating pumps will be taxed to capacity. A small bayou has been provided into which if necessary in very cold weather the circulating water discharge may be short-circuited thence directly through the intake flume and crib house to the pump suction.

Normally, however, the cooling water is taken through the pond directly from the lake and the discharge is carried back into the lake. A more definite idea of the arrangement may perhaps be had by reference to the map of the property shown in Fig. 1.

Electrical Equipment

Energy from the main generator unit is supplied to a double 12,000-v. bus in the switch house, from which are fed two commercial feeders, two station ties, two auxiliary transformers and two main step-up transformer banks.

Commercial feeders having a capacity of 500 amp. each, will supply a part of the load in the immediate vicinity of Waukegan. The station ties, also of 500-amp. capacity each, provide an emergency connection with station No. 1, the company's older plant in Waukegan.

The two station auxiliary transformers are three-phase water-cooled units having a capacity of 1800 kv.a. each which step the voltage down from 12,000 to 480 v. One of these units is held for reserve to insure continuity of power supply to the auxiliary equipment in case of a breakdown on the unit in service. The transformers themselves

Recapitulation of Mechanical Equipment

Sargent and Lundy.....Engineers H. V. Von Holst.....Architect

Boilers and Superheaters

Manufacturer	Babcock & Wilcox
Type	Inclined Header Cross Drum
Number installed	3 for one unit
Steam-making surface per boiler	14,086 sq. ft.
Grate area per boiler (18 ft. 3 in. x 21 ft.)	383 sq. ft.
Furnace volume	4300 cu. ft.
Size of tubes—	
8 rows in lower deck	3¼ in.
17 rows in upper deck	2 in.
Boiler operating pressure	400 lb.
Type of superheater	Integral
Manufacturer	Babcock & Wilcox
Location of superheater	Between upper and lower deck
Superheating surface	2286 sq. ft.
Superheat	250 deg. F.
Total steam temperature	700 deg. F.

Stokers

Manufacturer	Babcock & Wilcox
Type	Forced Draft Chain Grate
Number of stokers	3—One per boiler
Number of air zones per stoker	5
Grate area per stoker	383 sq. ft.
Drive per boiler, alternating current	10 hp. variable spd. motor
Arch radical end	M. H. Detrick Co.
Width of arch	21 ft.

Economizers

Manufacturer	Babcock & Wilcox
Type	"Duratex"
Location	Rear of boiler
Heating surface	8837 sq. ft.

Draft Equipment

	Induced	Forced
Manufacturer	American Blower Co.	Amer. Blower Co.
Type	Double Inlet	Double Inlet
Capacity, cu. ft. per min.	92,000 ea. at 350 deg. F.	60,000 each
Number of fans	One per boiler	One per boiler
Drive, motors, 440-v. variable spd., a. c.	150 hp. each	75 hp. each

Chimney

Type	Steel brick line
Number of boilers per stack	3
Height above grate	146 ft. 8 in.
Diameter of tip, inside	15 ft.

Coal Handling

To and from storage piles by 20-T. Browning Cranes	140 T. per hr.
From cars to bunkers by belt conveyor system (built by Koppers Co.)	140 T. per hr.
Track hopper to conveyor	Duplex Shaking Feeder
From feeder to Bradford breaker	36 in. belt conveyor
From breaker to end of boiler house above bunkers	Series of 3-24 in. belts
Distribution to bunkers	24-in. belt and tripper
Refuse from Bradford breaker	30-in. belt
Total length of belting used	2565 ft.
Total horsepower of conveyor drive	105 hp.
Horsepower of breaker drive	125 hp.

are installed out of doors, the low side feeding back into the station to the 480-v. station auxiliary bus supplying current for the station auxiliary motors which have a total name plate rating of 2211 hp.

One main transformer bank steps up the energy to 33,000 v. There are four single-phase units in the bank, one being held as a spare. Each unit has a capacity of 8333 kv.a., making the total bank capacity 25,000 kv.a. The units are water cooled and are installed out of doors doors. Both the main transformer banks are connected delta on the low side and star on the high or secondary side.

The 132,000-v. system feeds a substation west of Evanston where it is stepped down to 33,000 and 12,000 v. for sub-distribution. A map on which is indicated the main transmission lines is shown in Fig. 8.

Oil switches are provided for the generator, for each transformer, for each feed and for the 33,000-v. line. Mo-

Recapitulation of Mechanical Equipment

House Service Pumps

Manufacturer	Cameron Steam Pump Co.
Number	2
Capacity	750 g.p.m. each
Head	135 ft.
Number of stages	One
Drive	40 hp. turbine 2000 r.p.m.
	50 hp. motor 1800 r.p.m.

Boiler Feed

Number	3
Manufacturer	Cameron Steam Pump Co.
Capacity	500 g.p.m. each
Head	460 lb. per sq. in.
Type	5-stage turbine type centrif.
Drive	Two 250 hp., 2275 r.p.m., Westinghouse turbines
and	One 350 hp., 1750 r.p.m. G. E. Motor

Turbo-Generators

Manufacturer	Allis-Chalmers Co.
Type	Single-Cylinder Reaction
Capacity	27,777 kv.a.
Speed	1800 r.p.m.
Pressure at throttle	350 lb. per sq. in.
Superheat	240 deg. F.
Type of generator	3-phase, 60-cycle, 12,000-v.
Ventilating air	75,000 cu. ft.
Exciter, direct-connected	200 kw.
Air washer, 75,000 cu. ft.	Carrier Air Conditioning Co.

Condenser

Make	Allis-Chalmers Co.
Type	Horizont. two-pass cylindrical
Tube, surface	32,000 sq. ft.
1—Circulating Pump: 35,000 g.p.m.	Allis-Chalmers
2—Condensate pumps: 600 g.p.m.	Allis-Chalmers
2-stage, each driven by 50-hp. constant speed induction motors	
3—Air pumps: 30 cu. ft.	Croll-Reynolds

Miscellaneous Equipment

1 Boiler wash and fire pump, 3 stg. tur. driven, 500 g.p.m.	Cameron Steam Pump Co.
2 Extraction heaters, closed, 1480 sq. ft. each	Ross Heater & Mfg. Co.
1 Make-up heater, closed, 220 sq. ft.	Ross Heater & Mfg. Co.
3 Boiler soot blowers, valve-in-head, 22 units per boiler	Diamond Power Spec. Corp.
1 Air compressor, self-contained, 225 cu. ft. per min.	Westinghouse Trac. Brake Co.
1 Turbine room crane, 4 motors, 440 v., a. c., 100 T.	Whiting Corp.
Feed pump governors and drainage control	S. C. Manufacturing Co.
Feed water regulators	Northern Equipment Co.
Safety valves	Consolidated Safety Valve Co.
Blowoff valves	Edward Valve & Mfg. Co.
High-pressure steam gate valves and piping	Edward Valve & Mfg. Co. Crane Company
Sargol Welding joints	H. W. Johns-Manville Co.
Pipe coverings	Lewis M. Ellison Co.
Draft gages	Bailey Meter Co.
Indicating steam gages	Crosby Steam Ga. & Valve Co.
Recording thermometers	Industrial Instrument Co.
Feed water meters (Venturi)	Builders Iron Foundry
Steam-air flow meters	Bailey Meter Co.

at a 33-000-v. switch yard. This yard is an all-steel structure on which is mounted the 33,000-v. equipment consisting of a main bus, a transfer bus and the high tension switching equipment for four 33,000-v. lines.

The other main transformer bank steps up from 12,000 to 132,000 v. for one 132,000-v. line. There are four of these units, also, one being held as a spare, each single-phase unit having a capacity of 10,000 kv.a., making a 30,000 kv.a. bank. They are of the single bushing, graded insulation, water-cooled type and are also installed out of

tor-operated air break switches are used on the 132,000-v. line.

Reactors are installed between units in the main bus and on each 12,000-v. feeder. Oxide film outdoor type lightning arrestors are used on both the 33,000 and 132,-000-v. lines.

Vertical switchboards and a bench-board are located in the operating room just off the turbine room balcony and immediately adjacent to the switch-house. The generator and auxiliary transformers are controlled from the bench.

Of the three vertical boards one is for the 12,000-v. lines, station meters and battery charging equipment; one is for the 33,000 and 132,000-v. lines and the transformer banks; and the other for the station lighting system and the remote control for the field and exciter breakers.

Capacity for Rendering Service

Although the principle function of the Public Service Co. of Northern Illinois is to supply electric service to its customers, it also supplies gas and water and, in a few instances, central heating service. The electric service, however, constitutes by far the greater portion of its business.

As shown in the accompanying map, this company operates in 15 counties in northern Illinois. The territory served covers an area of about 6000 sq. mi. in which the population is about 750,000, excluding the city of Chicago. To serve efficiently its some 240,000 customers requires the services of almost 3800 employes.

With additions made and new properties acquired during the past year, the company now operates 18 electric generating stations both steam and hydro-electric, 8 gas manufacturing plants, and 28 electric substations. Electricity is produced by 51 generators and is distributed over nearly 800 mi. of high tension transmission lines ranging up to 132,000 v. Steam is produced in 96 boilers. The output of this equipment is about 1,000,000 kw.-hr. per day.

To assure itself of an adequate coal supply, the company owns several mines in Williamson Co., Ill., and Sullivan Co., Ind., under an arrangement whereby it obtains the right to the greater part of the production. During the year 1923 the company used about 475,000 T. of coal and the average consumption has been under 2.50 lb. per kw. hr. of energy produced.

Sampling Coal in Mines

MINE samples and delivered samples of coal are distinctly different, but analyses of these samples help to describe the character of the coal to the user, as pointed out by N. H. Snyder, fuel engineer, Department of Interior, in Technical Paper 344, just issued by the Bureau of Mines. Mine samples are collected according to a standard method. The sampler cuts a channel 2 by 6 in. or 3 by 4 in. from roof to floor in the face of the seam and excludes from the sample any partings more than ⅜ in. thick and any lenses or concretions of "sulphur," or other impurities, more than 2 in. in maximum diameter and ½ in. thick.

Analyses of mine samples form a permanent or scientific record of the coal bed at the point sampled; they are important in determining the character of the coal in any given mine or district. These analyses, when the samples are taken in a standardized manner, are valuable to the operator. When compared with analyses of delivered coal they show him whether or not his mine is being efficiently worked or whether the coal is being properly prepared—which involves the question whether he has suitable mechanical appliances for separating the impurities.

In the purchase of coal, mine samples may serve as a sufficient guide to the experienced purchaser who has knowledge of the impurities in the seam and the degree to which these are eliminated in mining and preparing the coal. To the average purchaser, unacquainted with these details, however, dependence on mine samples may be misleading. The quality of coal indicated by the face samples can rarely if ever be attained in the delivered coal. Certain impurities that are eliminated from the formally prepared mine sample may not be eliminated by the miner interested in getting out a large tonnage. Some of the roof and floor may also be included if these are soft or flaky. Some mine analyses, particularly those taken from geological reports, may be either from outcrop coal or small workings not beyond the influence of weathering. When coal prices are high and competition is lessened, it is easy for the miner and the management to lower the standards of preparation of the coal, and a return to rigid standards is always difficult.

In sampling delivered coal the Bureau of Mines follows a definite procedure. A sample of not less than 1000 lb. is systematically collected by taking equal increments at regular intervals throughout the delivery, while coal is being loaded or unloaded, and by crushing and reducing this sample by successive stages to laboratory size.

In using analyses of samples of delivered coal, one must recognize that coal is not always of uniform size and that the impurities are not uniformly distributed throughout the mass; hence there will be some variation in the results of sampling, and even though the same mass of coal is sampled a number of times, the analyses would not agree absolutely except by chance. It is only when a considerable number of analyses representing a considerable tonnage mined over a period of time are available that the average value and range of variation of a particular coal become known with certainty. With reasonable tolerance, however, for these variations, delivered coal can be sampled accurately enough for all practical purposes.

Delivered coal from any given mine may differ from day to day through variations in mining or preparing the coal; hence a record of analysis of delivered coal for any one time should not be considered as a permanent record, for the output may be greatly improved by new methods of mining and preparation; or, on the other hand, the output may deteriorate through carelessness in mining or preparation.

Bulletin No. 137, just issued by the Engineering Experiment Station of the University of Illinois, enunciates relations between the compressive strength of the concrete and the amount of the cement and voids contained therein. It develops methods for studying the concrete-making properties of fine and coarse aggregates and for the comparison and acceptance of aggregates. It outlines means for designing concrete mixtures for different densities and strengths when the voids in mortars made up with a given cement and fine aggregate have been determined by laboratory tests. Means are suggested for estimating the effect upon the strength and density of concrete that accompanies an increase in the amount of mixing water beyond that which would give minimum volume to the concrete. Analytical relations are developed and the technique for the proposed tests are described. The results of tests of mortars and concretes made up with a variety of fine aggregates are recorded and the accuracy and applicability of the methods discussed. The test data cover a considerable range—a variety of aggregates, different proportions of cement, and different amounts of mixing water—and the significance of the results is discussed. The application of the methods and principles deduced to design, specifications, and field use is considered.

Developments in the Use of Pulverized Coal

COAL WHICH HAS BEEN PULVERIZED CAN BE BURNED WITH A HIGH DEGREE OF EFFICIENCY. THIS IS PROVEN BY MANY INSTALLATIONS. BY CHARLES LONGENECKER

EARLY ATTEMPTS to secure successful operation with powdered coal were of a sporadic nature. In 1910 J. E. Blake applied this fuel to a boiler in the Henry Phipps power plant in Pittsburgh and in 1914 an installation along similar lines was made at the Peter Doelger Brewery in New York City. Those installations are of more than passing interest. Figure 1 shows the Phipps installation and Fig. 2 the Doelger. A study of these cuts reveals the striking similarity between the boiler furnace of 1910 and that of 1923. The only difference is one of furnace dimensions and details. If the designer had increased the depth of his furnace and changed his baffling, he would undoubtedly have achieved a high degree of success. In the Phipps design, automatic furnace control was used; this feature is desirable at the present time. The writer inspected this installation and distinctly remembers the small furnace volume and improper combustion resulting. Earliest successful installations of powdered coal, in this country, were on industrial furnaces and it is only natural that methods which were successful in firing these furnaces should be applied to boiler furnaces. While the application of heat followed diverse lines, it was not apparent that the two types of furnaces would not lend themselves to similar methods in firing. Following the practice on puddling and other large heating furnaces, the burners were installed along the same lines, horizontally. The results were not encouraging as the following test indicates:

Duration of test	18 hr.
Water heating surface, two boilers	9600 sq. ft.
Steam pressure by gage, lb. per sq. in.	149.3
Degree of superheat, deg. F.	74
Temperature of feed water, deg. F.	61.5
Temperature of escaping gas, deg. F.	437
Total weight of coal as crushed, including drier, lb.	48,160
Weight of coal used in drier, lb.	360
Total weight of pulverized coal fired in boilers, lb.	46,670
Total weight of dry coal fired in boilers, lb.	46,050
Total weight of water fed to boilers, lb.	383,800
Total equivalent evaporation from and at 212 deg. F., lb.	478,100
Percentage of rated capacity developed, per cent	77
Equivalent evaporation per lb. of coal as crushed, including drier coal, lb.	9.93
Equivalent evaporation per lb. of pulverized coal fired in boilers, lb.	10.24
Calorific value of 1 lb. of pulverized coal, B. t. u.	13,290
Efficiency of boilers including drier coal, per cent	74.2
Efficiency of boilers based on pulverized coal, per cent	74.8
Carbon dioxide in flue gas, by volume, per cent.	7.1

The capacity of the boilers as shown by this test is very low, which can be accounted for by the very small furnace volume.

In all these early installations, the principal reason for failure was due primarily to insufficient furnace volume, i. e., effective furnace volume. Whatever the position of the burner, there must be sufficient travel before the flame comes in contact with the tubes. The question of furnace volume has been one of considerable controversy. With the present practice of firing, there has been no practical demonstration to prove that furnace volumes as now adopted are not required. It is altogether possible that improvements may be made in firing the coal whereby less furnace volume will be necessary but such is not the case today. The rating at which the boiler is to be operated

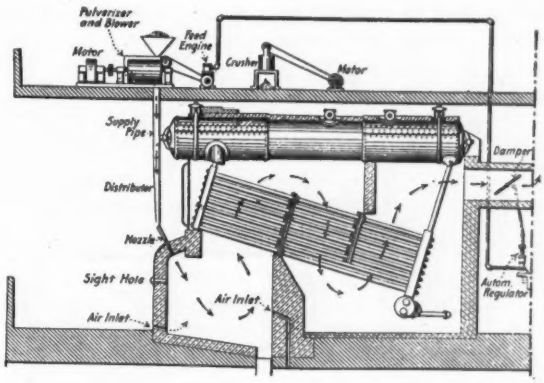

FIG. 1. PHIPPS INSTALLATION WAS MADE IN 1910

will determine the furnace volume, but at the same time the proportions must be correct. Expressed in cubic feet the volume may be ample but unless the combustion chamber is properly dimensioned efficiency and capacity will be lacking.

The question naturally arises: Why does a powdered coal furnace require such a long flame travel and large combustion space? The reasons are elemental to securing a high degree of combustion and proper conditions inside the furnace. They are:

First: To obtain the requisite close association of carbon and hydrogen with oxygen to insure complete combustion. It may be asked, why not do this in the burner or outside the furnace? In this connection, it will be apparent that while it may be possible to obtain a most intimate mixture of coal dust and air outside the furnace, we must secure in the furnace the union of carbon and hydrogen with oxygen. The coal must be gasified, which can only be done by heat, splitting the hydrocarbons into carbon and hydrogen and these elements then combined with the oxygen. This combination obviously must be effected in the combustion chamber. Undoubtedly a close mixture of coal and air at the burner outlet will promote combustion, but the chemical union, known as combustion, is a function of the furnace and cannot be performed outside of it.

Second: The time element. To carry to completion the above-mentioned chemical processes, especially where a large weight of the elements are involved, requires time. This may be only a question of, say, two seconds; but in

this time a particle of coal will travel its complete path in the combustion chamber depending on the draft and distance from burner to tubes.

Third: To afford the opportunity to dispose of a portion of the ash in the coal and to prevent fused ash from adhering to the boiler tubes. One of the indications of incomplete combustion is the amount of ash clinging to the lower row of boiler tubes.

Fourth: To prevent erosion of the brick work by the cutting action of the flame. Where the flame at a high velocity and temperature impinges on a brick surface, it will cut this surface.

Draft obviously must be properly regulated to insure correct furnace conditions. All boilers in plants, where economy of fuel is appreciated, should be provided with draft gages so there is no reason for not maintaining suitable draft. Powdered coal firing provides a most satisfactory field for automatic furnace control, as the fuel input is easy to regulate both as to quantity and length of time necessary for a change in quantity.

High CO_2 Cannot Always Be Maintained

There has been considerable difference of opinion as to the per cent of CO_2 which will give most satisfactory

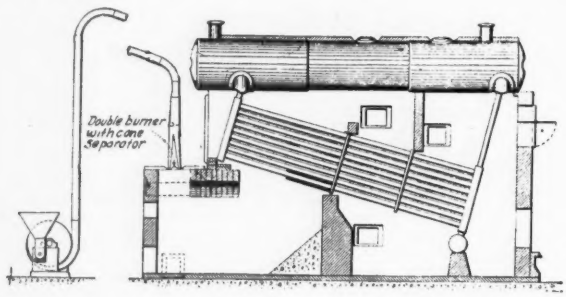

FIG. 2. IN 1914 THIS SETTING WAS INSTALLED AT THE PETER DOELGER BREWERY IN NEW YORK CITY

results. The higher the CO_2 the closer the approach to perfect combustion, but other features remain to be considered. At a plant where they are operating a total of 2080 hp. of boilers they report, "During the test the air supply was regulated in three different ways; namely, by use of the slide damper in the blast line, by the opening of the doors in the combustion chamber and by the use of the stack damper. The final method was found to be the best; for, as the damper was opened and a greater draft produced in the furnace, more air was drawn in. The damper was set to carry about 10 per cent CO_2 as it was found that the best results were obtained when running this way. With a higher CO_2 the furnace temperature became too great, causing slagging and fusing of the brick work and the evaporation rate fell off. To obtain the high CO_2 it was necessary to close down on the stack damper thus decreasing the velocity of the gases passing through the boiler. This caused the transfer of heat from the gases to the water to be slower, thus cutting down the evaporation for the same amount of coal. In this way, it was determined that a better efficiency was secured with about 10 per cent CO_2 than with 13 to 15 per cent. When the damper was closed down to obtain higher CO_2, the stack gave off heavy black smoke and as the damper was opened the CO_2 dropped and the stack cleared up until at 12 per cent CO_2 there was only a slight yellow haze issuing from the stack. As the temperature of the gases leaving the economizer is only 250 deg. F. and the percentage of heat lost in the stack gases is less than 7 per cent, the loss due to excess air was more than offset by the gain in evaporation and the longer life of the furnace lining with the lower temperature and CO_2."

As to the burner, there is much diversity in detail of design, but the same principle is followed in all. During the early days of experimentation, there was a prolific outpouring of burners and other contraptions, through which the coal had to pass. These burners have given way to the modern less complex type.

Information which follows is taken from two plants which are in successful operation today. The first plant has a battery of boilers of 600 hp. each. The first boiler was constructed with a furnace volume of 4.10 cu. ft. per rated horsepower. The depth of the furnace inside the burner arch was 13 ft. 6 in. and the distance from front wall to bridge wall was 12 ft. This boiler operated well at ratings up to 175 per cent of capacity. At higher ratings, there was a tendency towards slagging and deterioration of brickwork. Peak loads at 200 per cent of rating could be carried for short periods and no trouble experienced. This boiler was fired with powdered coal experimentally at first but the results were such that permanent equipment was put in place. From time to time, changes were made as seemed advisable; but at all times, the use of powdered coal was justified. If carried at 175 per cent of rating, there would be a small amount of slag formed; however, it was not of such a quantity as to cause trouble nor was it hard to remove. Three or four hours' work over the week end sufficed to clean the chamber of accumulations from a week's operation. The ability to pick up peak loads and ease of control with high efficiency were outstanding points in making this fuel acceptable. Stack draft averaged 0.36 in. while the draft in the furnace was on an average of 0.12 in. Temperature of stack gases ran from 430 to 500 deg. F. The boiler efficiency was from 76 per cent to 80 per cent with coal of 13,000 B. t. u. Steam pressure carried was 140 lb. A second plant operated boilers of 520 hp. The combustion space was 3.84 cu. ft. per rated horsepower. The following test shows the performance of one of these boilers:

List of a Modern Pulverized Coal Installation

1. Number and kind of boiler.....1 Babcock & Wilcox
2. Kind of furnace.....Pulverized fuel burning furnace
3. Volume of combustion space per boiler ..... 2,000 cu. ft.
4. Water heating surface in boiler... 5,201 sq. ft.
   (a) Water heating surface in economizer (ordinarily serves two boilers)..... 3,931 sq. ft.
5. Superheating surface..... 943 sq. ft.
6. Total heating surface of boiler.... 6,144 sq. ft.
   (a) Total heating surface of boiler and economizer .....10,075 sq. ft.
   (b) Ratio of water heating surface of boiler to volume of combustion space .....1 to 0.198
7. Date 6-15-20
8. Duration of test.....23 hr.
9. Kind and size of coal.....Bituminous coal

AVERAGE PRESSURES, TEMPERATURES, ETC.

10. Steam pressure by gage.....87.7 lb. sq. in.
    (a) Barometric pressure .....29.56 in. Hg.
11. Temperature of steam.....447.1 deg. F.
    (a) Normal temperature of saturated steam .....329.4 deg. F.
12. Temperature of feed water entering boiler .....166 deg. F.
    (a) Temperature of feed water entering economizer ..... 66.3 deg. F.
    (b) Increase temperature of water due to economizer..... 99.7 deg. F.
13. Temperature of escaping gases leaving economizer .....252 deg. F.
    (a) Temperature of gases, top of third pass .....474 deg. F.
    (b) Temperature of gases, bottom of second pass.....552 deg. F.
    (c) Temperature of gases, top of first pass .....939 deg. F.
    (d) Temperature of bottom of combustion chamber .....2312 deg. F.
14. Draft between economizer and fan.1.37 in.
    (a) Draft top of third pass..... .35 in.
    (b) Draft bottom of second pass.. .15 in.
    (c) Draft top of first pass..... .02 in.
    (d) Draft in combustion chamber. .26 in.
    (e) Blast pressure .....5.72 in.
(f) Differential pressure in blast pipe.5.64 in.
15. State of weather.....Cloudy and rain
    (a) Temperature of boiler room..90 deg. F.
    (b) Relative humidity of air entering furnace .....80 per cent

QUALITY OF STEAM

16. Number of degrees of superheat..117.7 deg. F.
17. Factor of evaporation based on temperature of feed water entering economizer, and degrees superheat 1.251
    (a) Factor of evaporation based on temperature of water entering boiler and degrees of superheat 1.149
18. Total weight of coal as fired.....54,994 lb.
19. Per cent of moisture in coal as fired .....0.94 per cent
20. Total weight of dry coal.....51,694 lb.
21. Ash and refuse (dry).....9055.1 lb.
22. Total combustible burned..... 42,637 lb.
23. Total weight of water fed to boilers467,423 lb.
24. Equivalent evaporation from and at 212 deg. F. based on temperature of water entering economizer, corrected for superheat in steam .....584,746 lb.
    (a) Equivalent evaporation from and at 212 deg. F. based on temperature of water entering boiler .....537,067 lb.

HOURLY QUANTITIES AND RATES

25. Dry coal per hour..... 2247.5 lb.
26. Dry coal per cu. ft. of furnace volume per hour..... 1.123 lb.
27. Equivalent evaporation per hour from and at 212 deg. F. based on water entering economizer.....25,423.7 lb.
    (a) Equivalent evaporation per hour based on temperature of water entering boiler....23,350 lb.
28. Equivalent evaporation per hour from and at 212 deg. F. per sq. ft. of total heating surface, based on water entering economizer... 2.52 lb.
    (a) Equivalent evaporation per hour per sq. ft. of boiler heating surface based on water entering boiler..... 2.31 lb.

CAPACITY

Based on Temperature of Feed Water Entering Economizer

29. Equivalent evaporation per hour from and at 212 deg. F.....25,423.7 lb.
    (a) Boiler horse power developed. 736.9 b. hp.
30. Rated capacity per hour from and at 212 deg. F.....17,940 lb.
    (a) Rated boiler horse power.... 520 b. hp.
31. Percentage of rated capacity developed ..... 141.7 per cent

CAPACITY

Based on Temperature of Feed Water Entering Boiler

32. Equivalent evaporation per hour from and at 212 deg. F.....23,350 lb.
    (a) boiler horse power developed. 676 b. hp.
33. Rated capacity per hour from and at 212 deg. F.....17,940 lb.
    (a) Rated boiler horse power..... 520 b. hp.
34. Percentage of rated capacity developed ..... 130 per cent

ECONOMY OF ECONOMIZER AND BOILER

35. Water fed per lb. of coal as fired.. 8.49 lb.
36. Water evaporated per lb. of dry coal ..... 9.04 lb.
37. Equivalent evaporation per lb. of coal as fired..... 10.63 lb.
38. Equivalent evaporation per lb. of dry coal ..... 11.31 lb.
39. Equivalent evaporation per lb. of combustible ..... 13.04 lb.
40. Calorific value of 1 lb. of dry coal by calorimeter .....12,610 B. t. u.
41. Calorific value of 1 lb. of combustible by calorimeter.....15,013 B. t. u.
42. Efficiency of boiler, economizer and furnace .....87.03 per cent
43. Efficiency based on combustible...84.28 per cent

ECONOMY

Based on Temperature of Water Entering Boiler

44. Water fed per lb. of coal as fired.. 8.49 lb.
45. Water evaporated per lb. of dry coal 9.04 lb.
46. Equivalent evaporation per lb. of coal as fired..... 9.76 lb.
47. Equivalent evaporation per lb. of dry coal.....10.38 lb.
48. Equivalent evaporation per lb. of combustible .....11.95 lb.

49. Calorific value of 1 lb. of dry coal by calorimeter.....12,610 B. t. u.
50. Calorific value of 1 lb. of combustible by calorimeter.....15,013 B. t. u.
51. Efficiency of boiler and furnace...79.87 per cent
52. Efficiency based on combustible...77.26 per cent
53. Proximate—
    (a) Moisture, per cent..... .94
    (b) Volatile matter, per cent....29.92
    (c) Fixed carbon, per cent.....52.56
    (d) Ash, per cent.....17.52
    (e) Sulphur, per cent..... 1.28

ANALYSIS OF FLUE GAS

54. (a) Carbon dioxide (CO_2), per cent 8.27
    (b) Oxygen (O_2), per cent..... 8.83
    (c) Carbon monoxide (CO), per cent ..... .166
    (d) Nitrogen (N) by difference, per cent 82.734

HEAT BALANCE BASED ON 1 LB. OF COMBUSTIBLE

	B.t.u.	Per Cent
(a) Heat absorbed by the boiler..	126.54	84.28
(b) Loss due to evaporation of moisture in coal.....	12.654	.084
(c) Loss due to heat carried away by steam formed by the burning of hydrogen.....	555.6	3.7
(d) Loss due to heat carried away in dry flue gas.....	990	6.59
(e) Loss due to carbon monoxide.	143	.952
(f) Loss due to combustible in ash and refuse.....	0	
(g) Loss due to heating moisture in air	45.1	.30
(h) Loss due to unconsumed hydrogen and hydro-carbons, unaccounted for and radiation...	613.0	4.08
(i) Total calorific value of 1 lb. of combustible 15,013		99.98

There can be little doubt as to the future growth of the powdered coal industry in relation to boiler firing. There were features which were a detriment to this growth, but such has been the history of all developments involving any radical changes in the burning of fuels. There was pioneer work to be done and with each change time had to pass before the effect of the change could be determined.

Cost of evaporating per 1000 lb. of steam is the item of most interest to the plant manager. What this will be is a problem which must be solved from those variables pertaining to the individual plant. The equipment selected must be proportional in first cost and in cost of operation to the amount of work (water evaporated) to be done.

ASH QUESTION NOT NECESSARILY TROUBLESOME

There are several points in regard to which those interested, in the fuel in question, may desire information. What becomes of the ash is the most frequent question. There are only three places for the ash to go. It may appear as slag in the combustion chamber or it may lodge at the bottom of the second or third passes or it may be discharged from the stack. What percentage of the whole will be found at these three points varies widely in different plants. In one plant running 24 hr. for six days, the accumulation from the combustion chamber and the second and third passes was removed by the labor of two men in 5 hr. What per cent was discharged from the stack could not be told. At another plant located in a business and residential section and burning approximately 4,500 lb. of coal per hour, no question has ever been raised as to the ash. It can be definitely stated that with proper care there will be no trouble from ash.

Furnace brick erosion is small where the furnace design is correct and the furnace is operated at a rating not too high for the size of the combustion chamber. It is admitted by engineers generally that heretofore there has not been sufficient space, in which combustion could be completed, in all types of furnaces whether hand fired, stoker fired or powdered coal fired. The advent of the powdered coal fired boiler accentuated this fact. The argument against the large volume required for burning powdered coal has therefore little weight because any furnace to burn the same weight of coal should be as large if the efficiency is to be high. Preheated air, which is now being used with powdered coal, will be another means whereby a further gain will be accomplished.

Possibilities of Electrical Developments in Japan

IN JAPAN, the electrical industry is potentially, the most important of all its industrial activities. Up to the time of the earthquake more money was being invested in this industry than in any other. The country is especially poor in coal and petroleum resources, so its manufacturing plants have been more or less dependent upon hydroelectric power and the ability of the Japanese to meet competition in the world market will depend to a great extent upon the future development of its hydroelectric resources.

In addition to furnishing cheap power for the manufacturing industries of the country, the electrical industry has also been a great factor in raising the standard of living of the Japanese people. A relatively large part of the energy produced is used for lighting purposes, and the foreigner traveling through out-of-the-way parts of Japan is surprised to find electric lights in small and almost inaccessible villages. Out of about 10,000 cities and towns in Japan proper, 75 per cent are supplied with electricity in one form or another.

The numerous short, swift rivers found in Japan have caused the development of electricity by water power to far outstrip that produced by steam, especially during the past decade. In 1910 the amounts produced by steam and by water power were about the same, but at the end of 1919 out of a total of 572,000 kw. produced by commercial light and power companies, 487,000 kw. were generated by water power, while only 94,000 were being produced by steam. The total production of all plants, including private and Government, during 1919 amounted to 1,133,000 kw. or about one-sixteenth that of the United States for the same period. The amount of paid-up capital invested in electrical enterprises at the end of 1919 amounted to 762,123,000 yen as compared with 169,201,000 yen at the end of 1910. The number of companies increased during that period from 191 to 581.

Effect of Increased Feed Water Temperature

BOILER EFFICIENCY IS NOT INCREASED BY RAISING THE FEED WATER TEMPERATURE, THE EFFECT IS TO GIVE THE BOILER LESS WORK TO DO. BY J. R. DARNELL

CONFUSION often results when an answer is sought for the question, "Is efficiency increased by increasing the boiler feed water temperature?"

In answering this question, many engineers will say that since by raising the feed water temperature you give the boiler less work to do you must of consequence use less fuel. This much is quite true. Reasoning further, they will say that since less fuel is used to do the same amount of work the efficiency must be increased because by efficiency we mean the ratio of the heat energy put in, to that taken out. But there is one serious flaw in this reasoning. In order logically and fairly to compare the performance of different boilers, or various performances of the same boiler, all variable conditions must be reduced to one standard condition. This is known as the equivalent evaporation which makes all boiler operations appear as if the water were introduced at a temperature of 212 deg. F. and evaporated at this same temperature and at atmospheric pressure. This condition is most generally expressed by the phrase "from and at 212 deg. F."

As a matter of fact, the feed water at one time may be 100 deg. F., the boiler pressure 125 lb. and the superheat 50 deg. F., or there may be no superheat. At another time, the feed water temperature may be 210 deg. F., the pressure 150 lb., with 100 deg. of superheat. Naturally there must be some such standard as mentioned above to which all these variables can be reduced.

How is this done? The first step is the determination of the factor of evaporation. Then, by multiplying the apparent or actual evaporation, i. e. the number of pounds of water evaporated per pound of fuel, by this factor we obtain the equivalent evaporation.

It is this factor of evaporation which is really the key to the whole situation. It is calculated by using the following formula:

$$\text{Factor} = \frac{H-h}{970.4} \qquad (1)$$

where,

H = Total heat in steam above 32 deg. F.

h = Sensible heat of feed water above 32 deg. F.

To illustrate the method of figuring the factor of evaporation, we will consider the conditions of steam pressure at 135 lb. ga., superheat 100 deg. F., and a feed water temperature of 160 deg. F.

H, for steam at 135 lb. ga. pressure and 100 deg. F. superheat, is 1249.6 B.t.u. and h will equal 160 minus 32, or 128, thus:

$$\text{Factor} = \frac{1249.6-128}{970.4} = 1.1558,$$ which is as shown in column 1 of the table given herewith.

To find the saving effected by increasing the temperature of the feed water we may use the following formula:

$$\text{Fuel saving per cent} = \frac{100\ (T-t)}{(H+32)-t} \qquad (2)$$

where,

T = temperature of water after heating

t = temperature of water before heating

H = Total heat of saturated steam above 32 deg., at boiler pressure.

Referring again to the table we will consider (column 1) a certain boiler performance with the feed water temperature at 160 deg. F. and in addition to the other items will assume that 13 lb. of water are evaporated for each pound of fuel oil used. With all data as shown, the calculated efficiency will be 78 per cent.

Now, consider the performance of this same boiler with all items identical except the temperature of the feed water and the pounds apparent evaporation. This latter item must of course be different in column 2 from column 1, since the increase in feed water temperature will cause more pounds of water to be evaporated per pound of fuel burned. How, then, shall we arrive at the figure showing apparent evaporation in colum 2? Referring to equation (2) and substituting the necessary values in the formula for fuel saving, we have:

$$\text{Per cent Saving} = \frac{100(210-160)}{(1193+32)-160} = \frac{5000}{1065} = 4.7$$

If one pound of fuel will evaporate 13 lb. of water as in column 1, then with 4.7 per cent saving 1 lb. of fuel will evaporate 13.64 lb. of water. This is the figure we must insert for item 7 in column 2. Having obtained figures for the apparent evaporation in each case we proceed in the usual manner to find the efficiency. Multiplying the equivalent evaporation by the latent heat of vaporization of water (970.4 B.t.u.) and dividing by the calorific value of the fuel, we obtain, in round numbers, 78 per cent efficiency for each performance.

Actually there is a slight increase (0.16 per cent) in efficiency as shown in column 2, due to assuming the same specific heat for water at 160 deg. as for 210 deg. But since in ordinary operation efficiency cannot actually be figured any closer than about 1 per cent, a value of 78 per cent for each performance is entirely acceptable.

TABLE SHOWING COMPARATIVE EFFICIENCIES WITH DIFFERENT FEED WATER TEMPERATURES

Item No.		Column No. 1	Column No. 2
1.	B.t.u. in one lb. fuel oil	18700	18700
2.	Boiler pressure, lb. ga.	135	135
3.	Feed water temperature deg. F.	160	210
4.	Degrees superheat	100	100
5.	B.t.u. total heat in steam	1250	1250
6.	Factor of evaporation	1.1558	1.1043
7.	Lb. apparent evaporation	13.00	13.64
8.	Lb. equivalent evaporation	15.03	15.06
9.	Efficiency, per cent	78.00	78.00

Although the apparent evaporation is higher in column 2 than in column 1 the equivalent evaporation is the same in both cases since the factor is lower in column 2 than in column 1. This is due to the fact that with the temperature of the feed water as shown in column 2, conditions

approach more nearly that of the standard. The higher apparent evaporation is an important item in considering fuel saving, but is not, in any way, an indication of efficiency. Since the equivalent evaporation is the same in both cases, the efficiency must be the same in spite of the fact that 4.7 per cent less fuel is used in one case than in the other.

Though many find it hard to understand, the fact remains that raising feed water temperature does not and can not increase boiler efficiency.

Editor's Note: Before a definite statement can be made, relative to the effects of waste heat feed water heating, it must be made clear whether the boiler alone or the entire plant is under consideration. It must be remembered that with other conditions remaining the same, an increase in the feed temperature will not result in an increased boiler efficiency, although the boiler will have less work to do and there will be a saving of fuel. The effects upon the economy of the entire plant will be a saving of fuel and an increase in the overall plant efficiency.

Possibilities of Improvements in Steam Plants*

DISCUSSION OF THE EFFICIENCY OF THE IDEAL HEAT ENGINE AND THE MARGINS AVAILABLE FOR IMPROVEMENT ALONG DIFFERENT LINES. BY ERNEST L. ROBINSON[1]

MANY INFLUENCES are tending to force manufacturers ot power to use greatest care in the layout of their plants in order to obtain the best possible economy of operation. The greatly diversified inventions requiring the use of electricity have much increased

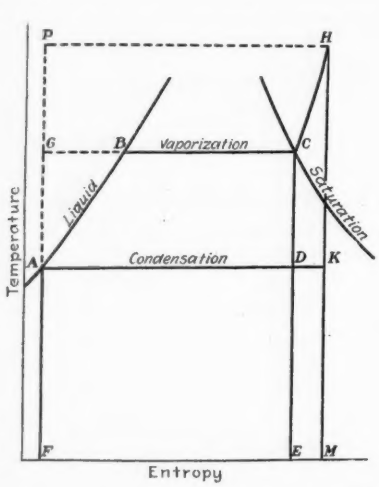

FIG. 1. TEMPERATURE—ENTROPY DIAGRAM FOR RANKINE CYCLE WITH SUPERHEATING

the demand for it. Existing plants are more and more pressed to the limit of their capacities and must get the largest output from the available equipment. Increasing costs of coal continually tend to emphasize the importance of the fuel charge in the total costs of operation, and point to the necessity of greater economy in its use; and a sentiment is growing more and more manifest that a high public spirit and the interests of the community require an economical use of natural resources.

It is appropriate, therefore, to take stock of the processes and methods available for improving steam-plant efficiency. The purpose of this article is to run over the whole field in a very general way, and to point out the limiting efficiencies attainable and show the lines along which the greatest margins for possible improvement lie. At the outset, then, practical and mechanical limitations will be disregarded in order to go first to the theoretically best economy.

IDEAL CONVERSION OF HEAT ENERGY

Fundamentally conceived, the steam plant is simply a heat engine for converting fuel into salable power. A heat engine receives heat from a hot source, does work, and rejects heat to a cold receiver. If the ideal heat engine could convert all of the heat into work, it would be necessary to reject the working substance devoid of all heat content, that is, at absolute zero. A working substance to carry the heat is of course essential. If, at any time energy is reclaimed from the working substance, without other heat exchange, its availability to do work has been decreased a corresponding amount, that is, its absolute temperature has been changed. Since the temperature of a condenser can hardly be lowered to absolute zero, it is necessary for heat engines in general to do work, even under ideal circumstances, at an efficiency far less than unity. This efficiency is represented by the actual temperature drop of the working substance divided by what the drop might be if all heat were abstracted, that is, the initial absolute temperature. This is the well-known Carnot-cycle efficiency and also the efficiency of any reversible engine.

Transfer of heat from a furnace at 2000 deg. F. to a boiler at 400 deg. F. is an irreversible process. Heat cannot be caused to flow by itself from the boiler to the hotter furnace. As a result of the decrease in temperature the availability of the heat energy in the steam at boiler temperature to do work is very much less than the theoretical availability of the same amount of heat energy in the furnace at the temperature of combustion. In fact, the idea of availability to do work is synonymous with thermodynamic efficiency, and this idea of loss of availability or thermodynamic efficiency in connection with the irreversible step is the important thing to note at this time.

TEMPERATURE LIMITS

Certain elementary conclusions are possible at once from this review of simple thermodynamic principles. It is desirable to have as cold a receiver as possible, and since there are practical limits to this coldness, it is also desirable to have the source of heat at as high a temperature as possible in order to give the widest possible operating range.

With steam as a working substance and modern turbine construction it has been found that vacuums corresponding to temperatures between 70 and 80 deg. F. are the best that can be obtained with the cooling water available. Likewise, at the other end of the process it

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happens to be far easier to produce high temperatures than to utilize their advantage, because, in the case of steam, the vaporization at a high temperature cannot be accomplished without confinement at an excessive pressure.

Thermal Processes

It is next important to consider the thermal processes and how closely they may be made to correspond with the ideal arrangement, that is, what sort of cycles can be used to the best advantage.

If, for the present, attention is confined to the furnace, it is plain that all the substance, fuel and air, which goes on to the grate and is heated must, in exactly the same quantity, disappear up the stack. Furthermore these substances which start at atmospheric temperature rise to the furnace temperature and then are returned to the atmosphere, eventually cooling to their initial condition. Considering the approach to and exit from the furnace, it is plain that equal quantities of substance rise on the one hand and fall on the other through equal ranges of temperature. This suggests the recovery of all the waste heat of the flue gases by regenerative air preheaters.

Next, considering the process of combustion, it may be regarded as a simple liberation of heat which occurs when the fuel and air are brought into contact at a high temperature. Suppose the fuel to be insulated from the air during preheating until the furnace temperature is reached, when combustion is permitted. Suppose the boiler to be so large that it will absorb the heat of combustion immediately without allowing any appreciable difference of temperature, the working substance being, in the ideal case, at the furnace temperature. This amounts to an isothermal transfer of heat and completes a reversible cycle in the furnace, at least from a thermo-dynamic point of view.

Furthermore, if the boiler is operated at a lower temperature than the furnace, the consequent loss of availability, according to the Carnot efficiency, must be charged against the boiler or its working substance and not against the furnace, since all the heat of combustion would still be transferred to the working substance.

The Engine. Rankine Cycle Not Ideal

Turning now to the working substance in the engine, the steam is the first consideration. It is not necessary to discuss the Rankine cycle for steam. Instead of the adiabatic compression of the Carnot cycle an increase of pressure at constant volume is used, a process which is not reversible. This is especially true in the case of superheat, even though it improves the actual efficiency. The ideal efficiency rises enormously faster than the change in Rankine efficiency with superheat. With saturated steam the conversion from liquid to steam in the boiler, the expansion in the turbine, and the condensation are all reversible processes, only the process of heating the liquid being irreversible. On the other hand, with superheated steam the absorption of heat is no longer isothermal, so that in this case two out of the four processes which go to make up the cycle are irreversible.

Extraction Cycle

The question now arises as to what cycle can be used in order to cause the steam to turn over the heat in accordance with the best theoretical standards. Obviously, the superheated-steam cycle is far from ideal. In fact, it is hard to justify the use of superheat from a purely theoretical viewpoint, although its application is thoroughly justified by a variety of practical reasons which will be discussed. The Rankine cycle with saturated steam has only one process, the feed heating, which is not reversible. The idea of a regenerative process consists in many small exchanges of heat occurring at successively different temperatures in infinitesimal steps. Suppose the steam-extraction process be pushed to such a limit. It has been called a regenerative process, and this is true.

Suppose steam is extracted from every stage of the turbine and that the number of stages is indefinitely increased. If at each stage just enough steam is extracted to heat the feed the infinitesimal temperature difference, each bit of steam so extracted has gone through a cycle reversible except for the infinitely small temperature drops during the feed heating, and these infinitesimal temperature drops occur in an unlimited number of small steps as in any regenerative process. The boiler temperature can thus be reached within an infinitely small amount. In other words, the extraction cycle as a whole is entirely reversible in the limit.

Steam extraction cycles with saturated steam are thus, in the limit, truly reversible processes with the ideal efficiency of the Carnot cycle. Furthermore the demonstration has assumed only the pressure-temperature relation of a wet vapor. It is good not only for steam, but equally correct for saturated ammonia or saturated mercury; however, it does not apply to the case of a superheated vapor. This is an important fact to understand clearly. The equivalence of the Carnot and extraction cycles was demonstrated in the days of the steam engine before the common use of superheat, and as a result the literature is not clear that the inference is true only for wet vapors and not for superheat.

This is about as far as abstract theory alone can go for the steam plant. The furnace and boiler have been imagined ideal by the use of regenerative air preheating with the flue gases, and the turbine has been imagined ideal by using saturated steam and heating the feed to boiler temperature by extraction. Thus the total margins for improvements are shown clearly in Fig. 1. It now becomes necessary to narrow the ideal still further by taking up the practical matters which determine the temperature limits and see what are the relative margins to gain among the various methods of increasing the efficiency. There are two principal questions: First, the temperature limits, and second, for established limits, how to approach as nearly as possible the ideal cycle.

Upper Temperature Limit

Upper temperature is determined by the materials of construction rather than by the furnace or the working substance. Turbine materials maintain their strength, roughly speaking, up to 700 deg. F. Turbine steels are usually good up to 800 deg. F., but the gradient of decrease in strength per degree rise of temperature becomes so steep at higher temperatures that only very low stresses are allowable.

The temperature-enthropy diagram is useful for visualizing the differences in the processes. Figure 1 shows the Rankine cycle *ABCD*. The heat put in is represented by the area *FABCDE* and the heat exhausted by the area *ADEF*. The Carnot cycle working between the same temperature limits has an efficiency which might be repre-

sented by certain areas constructed by drawing the lines *AG* and *GB*. For the same heat exhausted as in the Rankine cycle, the Carnot cycle would have to absorb heat *FGCE* and deliver work *AGCD*. It is plain, therefore, since the extraction cycle is equal in efficiency to the Carnot cycle, that it is represented by these areas, although only as areas, because the broken lines do not represent properties of the substance. Now with the superheated Rankine cycle the work area *DCHK* is added out of a heat addition of *ECHM*. The efficiency is raised because the added work area is a larger ratio of the added heat area than the original efficiency. But the work area of the Carnot cycle for the elevated temperature is represented by the area *APHK*, so that the small addition *DCHK* is a ridiculously unsatisfactory approach. Moreover the constant pressure line *BCH* is no longer isothermal.

Advantage of High Pressure

In order to get the thermodynamic advantage of the highest temperature reached the steam must be generated

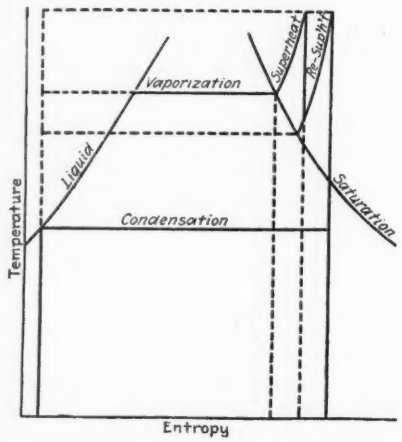


FIG. 2. TEMPERATURE—ENTROPY DIAGRAM WITH RESUPERHEATING

at that temperature, a process which is practicable only for wet steam and provided that the required pressure is maintained. Thus it is clear that, due to the nature of a vapor, the pressure is quite as important as the temperature. Even at 1000 lb. per sq. in. the properties of steam are not known with precision.

Binary-Vapor Turbine

This points to the necessity of a substance whose vapor pressure will not be excessive at the temperature to which the materials of construction may be submitted. And this is the great advantage of the mercury turbine which can be operated at an initial pressure of about 45 lb. per sq. in.

Advantage of Steam Extraction

Having thus discussed what the theoretical efficiency is and how various practical limitations determine what is ideal in any particular case, the next matter to consider is the utilitarian question of the value of the various improvements already instituted. The idea is to take up step by step various limitations that lie between the application of the perfectly general theory and present steam-plant methods. The advantage of the mercury turbine has been pointed out. Roughly it may be said that, in comparison with no feed heating, the use of one heater will realize between a third and a half full theoretical gain, and also, roughly, that each additional heater will realize an improvement about half as large as the last preceding heater added to the system. It remains to discuss the advantage of or reason for superheating, resuperheating, drying, the economizer, air preheating, and the use of auxiliary feed water heaters.

Advantages of Superheat

Advantage of superheat, as mentioned before, is almost entirely of practical application due to the limitation of a high initial pressure. The desired temperature cannot be attained with wet steam without incurring too high an initial pressure. Hence the pressure is pushed as high as possible. Fortunately, the use of superheat is attended with a non-thermo-dynamic improvement in efficiency which is roughly of the same order of magnitude as the theoretical improvement. This is attributed to removal of moisture in the lower stages of the turbine. And still further the greater heat turnover per pound of steam results in an even greater reduction of water rate, which is advantageous in permitting a larger capacity rating of the machine, as will be discussed in another place.

In order to visualize these advantages it may be said, very roughly, that the theoretical gain in economy is about 1.5 per cent for 100 deg. F. superheat, while the non-thermodynamic gain is about as much more, making an overall reduction of heat rate in the neighborhood of 3 per cent per 100 deg. of superheat. The reduction in water rate is, on the other hand, of the order of 8 per cent per 100 deg. F.; however, this must be clearly distinguished from an increase in the economy of operation of the plant. A reduction of water rate does not mean a corresponding reduction in the fuel rate because reductions in water rate usually entail a substantial increase in the heat per pound absorbed by the steam in the boiler.

Resuperheating

Desirability of resuperheating is due largely to the same reasons that apply in the case of initial superheat. But the newness of the process makes it less easy to say what the gain may be beyond the theoretical amount. Figure 2 shows at a glance that the cycle has been improved, roughly, by nearly the same degree as in the case of initial superheat as compared with saturated steam. The process is accompanied by a further reduction of water rate, as explained before, which is greater than corresponds with the reduction in heat rate. In passing it may be noted that this resuperheating process is a sort of partial expansion under isothermal conditions. For instance, if the resuperheating should take place in each stage, this isothermal expansion might go on to exhaust pressure. There would be a slight additional gain in economy, but the efficiency of the process would not approach the efficiency of the Carnot cycle. The possibilities of practical application to any particular advantage are limited to about one or two steps of resuperheating.

Drying

Drying may be accomplished by the same process as resuperheating, namely, by the addition of heat; but if the addition of heat is only sufficient to dry the steam without superheating it, the gain will be slight and due

largely to increased mechanical efficiency in the process of energy conversion. On the other hand, if the drying is done by moisture abstraction, the gain is very appreciable. The moisture removed should be used for feed water heating, and the practical rise of efficiency due to drier steam in the turbine should be realized.

Economizers

In all that has been said so far, there has appeared no place for an economizer. Indeed, as far as the theory goes, it appears to be anomalous. In considering the ideal furnace, it was pointed out that flue-gas heat should be transferred to the entering air, and in considering the extraction cycle the logical source of feed water heat was seen to be extracted steam. The economizer is intentionally aimed to extend the boiler process to a temperature below that corresponding to its pressure; i.e., to destroy its isothermal nature. But in all these cases where a substantial practice has grown up there is always a good common-sense reason sufficient to justify it at the time. The discharge of hot flue gas was a material waste. To pump cold water into a hot boiler was bad; and the transfer of heat from hot gas to water was a practical process well known, since it was taking place in every boiler; hence the economizer. The economizer works at temperatures roughly between 300 and 600 deg. F., whereas grate manufacturers prefer the air to enter the furnace at a temperature less than 300 deg. F., or certainly not much more. The inability to utilize this flow of fluid for returning low-grade heat to the furnace means definitely a corresponding amount of waste. Here is a good reason for pulverized fuel, if it will permit the use of very hot air going to the fire.

Air Preheating with Extracted Steam

Use of extracted steam for air preheating is another scheme. If the economizer is used at the same time, it will be observed that the recommended arrangements of the ideal process have been crossed. In detail, instead of recovering the low-grade heat by the two regenerative processes, flue gas to air and extracted steam to feed water, the following processes have been substituted: Flue gas to feed water and extracted steam to air. This is all right as far as it goes, but examination shows that the criss-cross is not equivalent to the direct process.

Still another arrangement occurs to the author. The economizer must receive reasonably cold water in order to work efficiently, whereas the extraction process is not pushed to its limit unless it heats the water to boiler temperature. Present arrangements send the feed water from the heaters to the economizer, thus dividing the available temperature range between the two heating devices. A more efficient way than to divide the temperature rise would be to divide the circulation into two very roughly equal parts (supposing pulverized fuel and no limitation on the air-preheating temperature). One branch of the system would be sent to the economizer as it comes from the hotwell and should enable the cooling of the flue gases to a materially lower temperature than with feed water already preheated. The other branch of the system should be arranged to receive extracted steam, including appropriate amounts from the high-pressure stages, since these temperatures no longer detract from the action of the economizer. Similar amounts of extracted steam would be used for preheating the air. Such a process in perfect adjustment would approach the ideal process.

It is now time to mention the use of a house turbine for feed water heating. If the house turbine has the same efficiency as the main units it is exactly equivalent to single-stage extraction. A house turbine is rarely as efficient as the main units, and generally means a less economical heat rate than extraction from the main units.

Steam Auxiliaries for Feed Heating

If steam auxiliaries are used for other reasons, the exhaust heat from these may be used for feed-water heating. It is interesting to read descriptions of this common practice which seem to reflect an opinion that it is desirable to create a number of losses in order to have losses to recover. Steam auxiliaries are usually inefficient as compared with the main unit and therefore not to be compared with motor drive. In consequence the use of such heat is a waste as compared with extraction from the main unit.

Other Sources of Low-Grade Heat

There are also several other sources of low-grade heat about the station which may be used for feed-heating purposes. Among these may be listed the following possibilities: The exhaust from the turbine high-pressure packings; the heat of the steam air ejectors; the heat of the bearings as recovered from the oil coolers; the generator losses as recovered in the generator cooling-air circulation.

Importance of considering the station heat rate as a whole is not always appreciated. As soon as the boiler plant and the turbine plant are connected by the regenerative processes the whole station becomes a single thermodynamic unit, and it is no longer possible to judge its economy by considering separately the boiler and the turbine.

Capacity Rating

In conclusion, it seems necessary to consider the effect of the various improvements on the capacity of a unit. This relation has been noted repeatedly in passing, and it is a fortunate circumstance that improvements in efficiency usually result in a greater power output from a given amount of working substance and thus tend to increase the rated capacity of a machine. In the case of a particular turbine of large size, the rating depends on the volume of steam passing the last wheel so that reductions of water rate, especially water rate at the last wheel, cause corresponding increases in the rated capacity of the turbine. The reduction of water rate with superheat has been mentioned. A similar reduction occurs with increased pressure. The effect of steam extraction is obviously to reduce the water rate at the last wheel. Recent advances in the rating of single turbine units have brought the importance of this subject to the front, and it seems necessary to point out here the great increase in capacity which theory alone provides in the case of machines using the improvements which have been discussed.

In the case of increased superheat at a fixed pressure the capacity rating of the machine increases less rapidly than the capacity per pound on account of the greater exhaust volume. On the other hand, with increased pressure at a constant superheat the capacity rating increases more rapidly than the capacity per pound because of the reduced exhaust volume. Generally speaking, increases of superheat have been accompanied by increases of pressure, so that exhaust specific volumes have been changed very little.

Mercury Boiler in Successful Operation

COMBINATION MERCURY AND STEAM CYCLE SHOWS REMARKABLE SAVINGS AT HARTFORD ELECTRIC LIGHT CO. PLANT

FROM TIME to time during the past few years, interesting reports have been passed around regarding the development work on the mercury turbine which is being carried on by the General Electric Co. in conjunction with the Hartford Electric Light Co. Recently the work reached the point where the first plant for commercial operation was placed in service and although, even yet, there is much development work to be done before the mercury turbine is placed on a commercial basis, the practicability of the mercury cycle seems assured.

In order to gather some first-hand impressions and to secure the opinions of the executives of the operating company as to the future possibilities of this development, a representative of Power Plant Engineering recently visited this plant and talked with representatives of the Hartford Electric Light Co. and the General Electric Co. concerning it.

"Present operating results with the mercury boiler and turbine are such as to warrant belief in the success of this development" was the way T. H. Soren, vice president of the Hartford company summed up the situation. "The installation has been carrying a part of the load at the Dutch Point station and while the unit is now operating at about half its rated load it will gradually be brought up to full rating and then in all probability will be tested at over-rating in order to determine exactly what it will do."

"During this time," states Mr. Soren, "accurate tests will be run in order to determine the economies at the various ratings. Present tests are more for determining the life and reliability of the equipment than to determine its efficiency."

No actual test figures as to the economies of the mercury cycle have been given out although general data show that a kilowatt-hour is produced at the Dutch Point station for about half of the former coal consumption. According to Mr. Soren, if the installation is applied to a steam station of high efficiency, say about 18,000 B.t.u. per kw.-hr., the use of the mercury boiler and turbine in conjunction with such a station might reduce this to about one-half that rate.

One of the beauties of the scheme in his opinion is the fact that it is purely a boiler room improvement, in other words it can be applied to existing stations without disturbing any of the equipment beyond the main steam header. It is planned, for instance, to install a mercury unit at the South Meadow station in Hartford. One of the 1400-hp. boiler units will be removed and the mercury boiler with the mercury turbine, condenser and generator

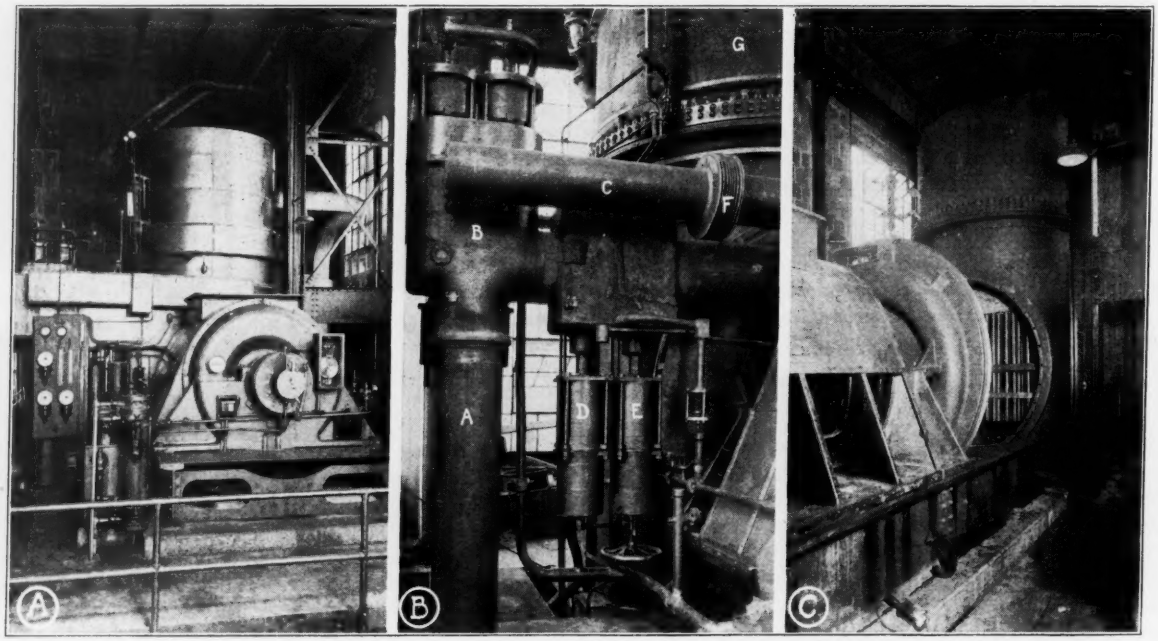


FIG. 1. MERCURY VAPOR PASSES THROUGH TURBINE AND CONDENSES INTO CONDENSER-BOILER WHERE STEAM IS GENERATED

A. Condenser-boiler, mercury turbine and generator unit is shown in this view. This part of the equipment is located on the floor above the mercury boiler as shown in Fig. 2.

B. This view was taken before the instrument panel was put in place and before the piping and turbines were lagged. The pipe marked "A" is the mercury vapor pipe leading from the boiler while "B" is the special safety valve which bypasses the vapor into the condenser through pipe "C," should the boiler pressure rise above a pre-determined point. "D" is an electrically controlled emergency valve while "E" is an electrically controlled governing valve. An accordion expansion joint located at "F" relieves the expansion and contraction strains in the line between the safety valve and the condenser. The steam drum of the condenser boiler is the part marked "G."

C. Mercury vapor passes around the water tubes of the condenser and in condensing gives up its heat to the water. This view is from the opposite side shown in the left hand picture and was taken before the connection was made between the mercury turbine and condenser-boiler.

above it, will be installed in its place. In the ordinary station it is probable that the boiler room roof would have to be raised but in the South Meadow station the original design was laid out with the idea of installing mercury units, if they should come up to expectations.

As a concrete illustration of what this would mean in the way of increased capacity for present steam stations, Mr. Soren cited the fact that the 1400-hp. boilers at South Meadow have been operated to supply steam for about

ments were constantly being made in steam turbines, of course, and their efficiency was gradually being increased. But this is an enormous stride forward. Yes, it is a revolution."

"Our fuel bill last year was something like $1,500,000. The 13 tons of mercury required for the new boiler cost about $20,000, can be used indefinitely and will produce more than twice the energy from the same amount of coal. It is plain, then, that when the mercury boiler is perfected

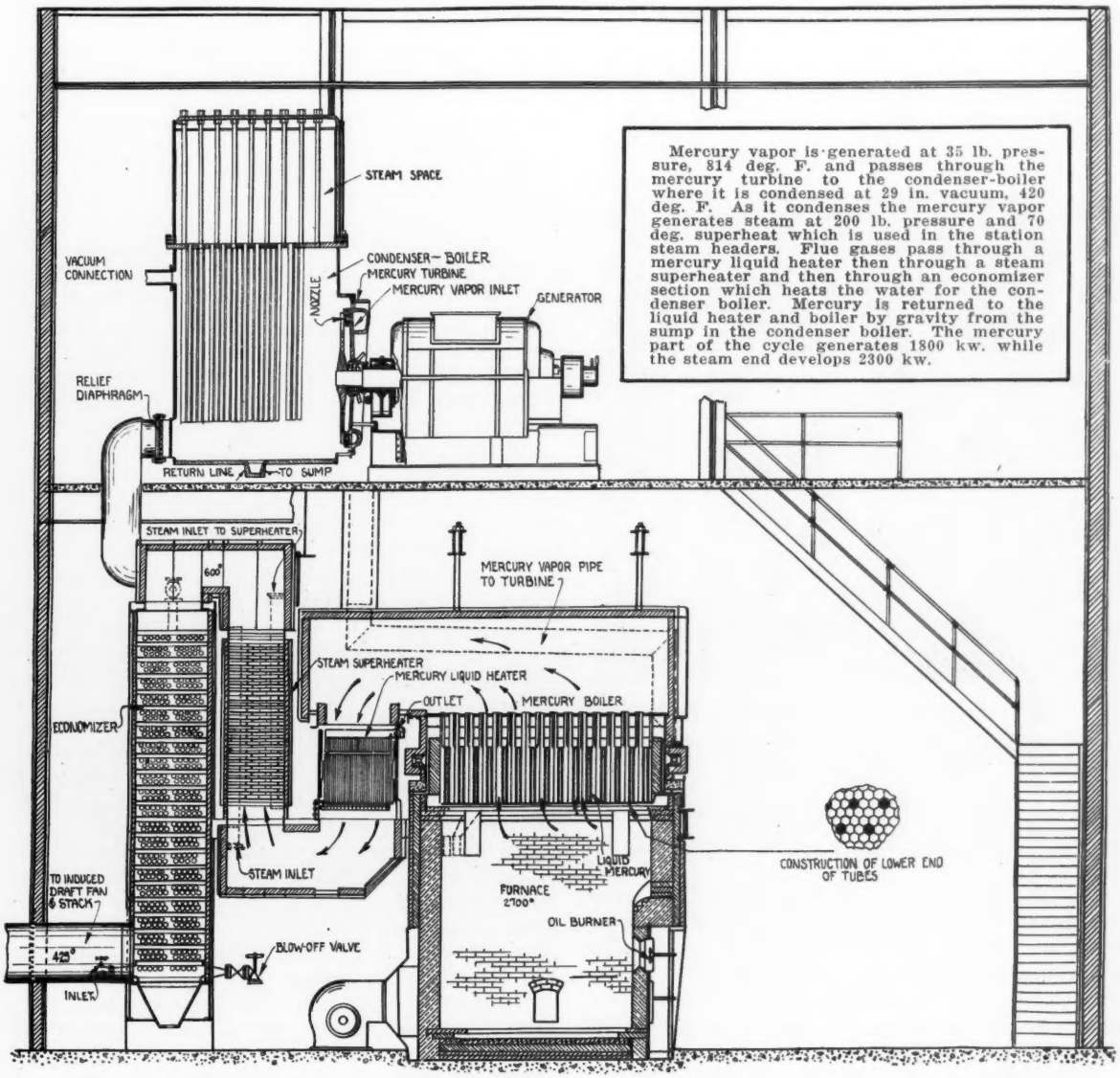

Mercury vapor is generated at 35 lb. pressure, 814 deg. F. and passes through the mercury turbine to the condenser-boiler where it is condensed at 29 in. vacuum, 420 deg. F. As it condenses the mercury vapor generates steam at 200 lb. pressure and 70 deg. superheat which is used in the station steam headers. Flue gases pass through a mercury liquid heater then through a steam superheater and then through an economizer section which heats the water for the condenser boiler. Mercury is returned to the liquid heater and boiler by gravity from the sump in the condenser boiler. The mercury part of the cycle generates 1800 kw. while the steam end develops 2300 kw.
STEAM SPACE
VACUUM CONNECTION
CONDENSER-BOILER
MERCURY TURBINE
MERCURY VAPOR INLET
NOZZLE
GENERATOR
RELIEF DIAPHRAGM
RETURN LINE
TO SUMP
STEAM INLET TO SUPERHEATER
600°
MERCURY VAPOR PIPE TO TURBINE
STEAM SUPERHEATER
MERCURY LIQUID HEATER
OUTLET
MERCURY BOILER
ECONOMIZER
TO INDUCED DRAFT FAN & STACK
425°
INLET
STEAM INLET
BLOW-OFF VALVE
LIQUID MERCURY
FURNACE 2700°
OIL BURNER
CONSTRUCTION OF LOWER END OF TUBES

FIG. 2. EQUIPMENT IS SO ARRANGED THAT THE MERCURY RUNS BACK INTO THE BOILER BY GRAVITY

8000 kw. in generator rating with 10,000 kw. as a maximum. The use of the mercury unit will raise this capacity to about 18,000 kw. without materially increasing the coal consumption. After more complete operating experience has justified the use of the mercury units it is probable that additional units will be placed in the South Meadow station.

"It is safe to say that the mercury boiler is a revolution in the generation of electricity," declared Vice-President Samuel Ferguson of the Hartford company. "Improve-

and comes into general use, electricity can be produced for less than the present cost. Another point to consider is the relief to the railroads in having coal loads lessened."

From the installation and initial operation standpoints, the mercury boiler will be a costly experiment, for Mr. Ferguson estimates that his company and the General Electric Co. will spend a half million dollars on the experiment.

In speaking of the development of the mercury boiler, H. N. Hackett of the General Electric Co. who has super-

intended the installation work and who has been associated with Mr. Emmet, the designer, stated that the main idea had been to get an outfit which would work. The economic possibilities of the scheme have been so great that the sole idea has been to take advantage of the first big saving by the use of rugged and reliable equipment and then to carry out the refinement which would give added efficiency. Higher mercury pressure, use of a multi-stage mercury turbine and a more efficient mercury boiler are possibilities of the future which will no doubt be worked out after more complete operating data are available.

Referring to the diagram shown as Fig. 2 it will be noted that the essential parts of the plant located on the first floor consists of a fire box, mercury boiler and breeching in which are mounted the mercury liquid heater, a superheater for the steam and an induced draft fan, while

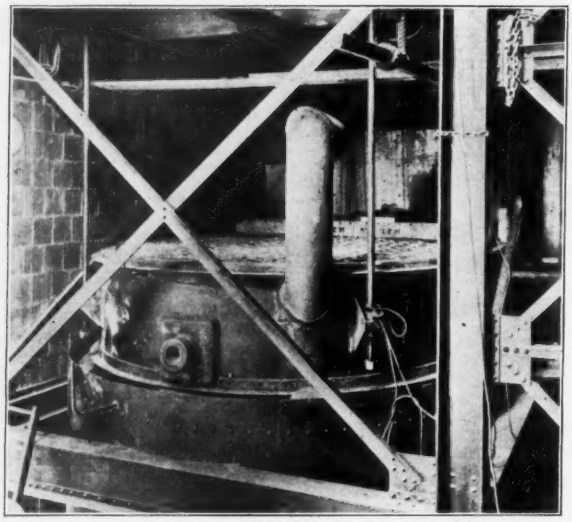


FIG. 3. TOP OF MERCURY BOILER BEFORE FLUE CASING WAS INSTALLED. THE PIPE SHOWN IS THE VAPOR CONNECTION TO TURBINE

on the second floor is located the mercury turbine condenser-boiler and the generator all tied together as one unit.

Oil firing is used in the furnace and the flue gases, after passing through the fire tubes of the mercury boiler, pass through the flue casing to the mercury liquid heater, then to the superheater for the steam coming from the condenser boiler and then through the economizer section which heats the feed water, then out through the induced draft fan and into the stack.

Mercury which is vaporized passes to the mercury turbine through the vapor pipe which is shown at the top of Fig. 3. This particular view was taken before the flue casing was placed above the boiler.

After the mercury vapor passes through the single-runner mercury turbine, it passes directly into the condenser-boiler. As shown in Fig. 1C the cooling effect of this condenser is obtained by water tubes which are closed at one end and which are welded into a water and steam drum at the other end. As the mercury vapor condenses, it gives up its heat to the water and steam is generated; hence the name condenser-boiler. As the mercury condenses, it runs back by gravity to the liquid heater, thence to the boiler. Steam which is generated passes into the station steam headers.

In the present design the upper ends of the tubes are expanded and then welded into a tube sheet. The lower two-thirds of each tube is hexagonal in shape with the sides slightly rounded. These sides are welded together at the ends of tubes making a construction as shown in Fig. 2. The space between these hexagonal sides therefore holds a film of mercury. In order, however, to provide for a better circulation one tube in every seven is left out as shown by the black portions of the drawing.

One object of this design is to provide the maximum heating surface and at the same time reduce the mercury content to the minimum. The construction has the disadvantage that the boiler is inaccessible for cleaning.

It is expected that the next boiler will be of the inverted V-type with the mercury contained in tubes. The lower headers will be arranged so that the bottom part can be cut off with a welding arc, the tubes cleaned and the head welded on again. With this construction it is expected that the mercury required will be reduced from 7.3 lb. per kw. as in the present boiler to about 4 lb. per kw. of total capacity.

No particular difficulties were encountered in the design of the mercury turbine. The present machine is of the single-stage impulse type with tool-steel blading and the glands are sealed with illuminating gas.

In order to reduce the possibility of air leakage, the condenser is not only bolted to the turbine casing but is also welded. The mercury sump is also protected by a gas seal and in addition a strainer is used to remove any oxide contained in the mercury. If it is desired to shut the plant down, illuminating gas is turned into the turbine and condenser to prevent the possibility of air admission. These precautions are all taken with a view to reducing oxidation of the mercury which would not only cause a loss in mercury, but would be likely to clog the circulation in the boiler.

One of the first thoughts that occurs to the engineer in considering the mercury cycle is the possible hazards in case of a leakage of mercury vapor into the station. In the opinion of Mr. Soren, there is less hazard with escaping mercury than escaping high pressure steam, for the reason that the mercury vapor is heavy and almost instantly condenses when it reaches the atmosphere. This condensation is practically complete. It does not flow around as steam or gases do. The appearance of a leak in the vapor pipe is merely a few drops of liquid mercury in the immediate vicinity of the leakage.

In order to conserve mercury a special type of safety valve is used whereby the mercury vapor is bypassed into the condenser should the boiler pressure rise above a predetermined point. A relief diaphragm is also provided in the condenser with a connection to the economizer section of the flue passage, for protection in case of a failure of the vacuum.

In the plant as it is at present designed mercury vapor is generated at 35-lb. pressure, 814 deg. F. and passed through the mercury turbine to the condenser at 29 in. vacuum and a temperature of 420 deg. F. This part of the cycle generates 1800 kw. and the heat given up by the vapor in condensing generates about 2800 lb. of steam per hr. at 200-lb. pressure and 70 deg. superheat. This steam used in the regular station operating cycle of the Dutch Point station adds about 2300 kw. to the output.

Overhauling a Diesel Engine

WHERE TO LOOK FOR WEAR AND HOW TO HANDLE THE REPAIR WORK. BY M. S. HOWARD

WHILE the actual wear of parts in a Diesel engine is small, nevertheless a general overhauling is needed about once every 5 yr. The operating engineer should be in a position to do this overhauling without calling in the manufacturer's trouble man. Many engineers, however, dread this job for the reason that they do not know where to look for wear and needs of adjustment, nor do they know how to proceed with the work of dismantling and overhauling.

In an oil engine, the principal places to look for wear are in the piston, the cylinder liners, the piston pin bearings, the crankpin bearings, the main bearings, the governor shaft gears, the fuel pump and in the valves and gear.

Before an engine is shut down for overhauling, the engineer should take indicator cards so that he may see if the compression is correct. He should keep a note book and set down in it his observations as to the engine's behavior.

One of the first steps is to assemble all the wrenches, emery paste, plumb bobs, spirit levels and calipers that he feels he may need. The crankcase doors should be removed, taken off and all oil piping removed in order to render the machine accessible. The various pipe joints at the cylinder heads should be opened and the cylinder heads removed.

One way to remove the heads is to screw three eyebolts into tapped openings in the head. A rope sling is then passed through these eyebolts and hooked onto the overhead crane hoist as shown in Fig. 1. The valve rocker arms and valve cage should, of course, have been already removed and placed at a safe distance from the machine.

The next step is to lift out the pistons. To do this, the connecting rod must be unshipped from the crankpin. This means that the end bolts must be removed as the space within the crankcase is limited and it is impossible to get at the nuts on these bolts from inside the crankcase. The engine must be turned over until one of the bolts can be reached by putting the wrench in through the frame door with the handle sticking out. A few sharp blows on the wrench will start the locknut, which should be entirely removed. The lower nut is then loosened a few turns, but not taken off. The engine is then turned over until the second bolt can be reached through the opposite side. This is shown in Fig 2. The locknut on this bolt is removed and the lower nut slackened off. The engine is then turned so that the crank is vertical; the crank hook then is slipped through the eyebolt already screwed into the piston crown.

If the engine has a trunk piston, the best plan is next to slip two 2 by 4-in. timbers across the crankcase and block it up until they almost bear against the lower bearing half, but clear the bolt heads, as in Fig. 3. The nuts are removed and the crank bolts are now driven down through the bearing housing with a copper mallet. The connecting rod is now free from the crankpin box and the piston along with the rod is lifted out of the cylinder by the hoist. The top half of the bearing is tilted over onto the 2 by 4 and slid out through the door. To remove the lower bearing half, enough of the blocking is removed to allow the bearing to clear the crankpin.

Similar procedure is followed on all the pistons. Each bearing is numbered as are the bolts, and the men should note this and be sure to place each bearing with its proper rod.

Next the crankshaft is taken out. This is the most difficult of all jobs and too many engineers give it "a lick and a promise" of examining it next time. The consequence is that a bearing may be low and remain undetected —resulting in a broken shaft some day.

In removing the shaft, the coupling joining the shaft and the short extended shaft which carries the flywheel and generator is unshipped. After the journal caps are lifted out, the shaft is slung from two overhead trolley hoists and moved lengthwise out of the end of the crankcase. If the engine is a four-cylinder unit the cranks are 180 deg. apart

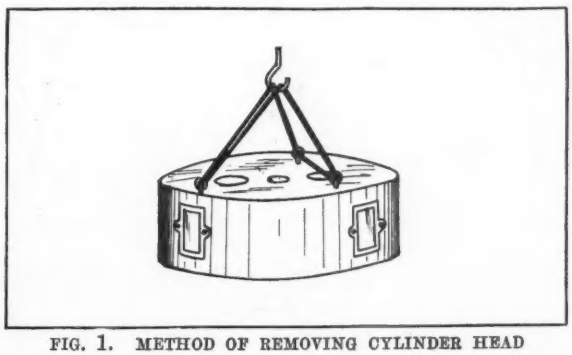


FIG. 1. METHOD OF REMOVING CYLINDER HEAD

and it is not difficult to get the shaft out of the narrow end opening. If a three, five or six-cylinder engine, the crank throws are at such angles that the shaft must be turned as the cranks pass the several bearings to avoid the bearing cap studs.

As the main part of the engine is now on the floor, the process of examination begins.

When taking indicator cards before shutting down, the engineer is able to discover whether the compression in one or more of the cylinders is low. We will assume that one of the cylinders shows a compression pressure of 350 lb. The first thing to do in the examination is to discover the reason for this, for the pressure should be about 475 lb. Several things may cause this loss which may be listed as follows: Stuck piston rings preventing a sealing of the clearance between piston and lever; the piston body may be worn enough so that the rings are unable to hold the air pressure; the liner may be worn or scored; the valves or valve cages may not be sealing properly and so allow the air to escape or the connecting rod bottom end may not have enough shims between it and the crankpin bearing.

Unless the connecting rod is the right length the piston will not go up far enough and the clearance space between the piston and cylinder head may be too large. This clearance should be about 1/14 of the distance between the head and piston when the piston is at bottom center. The engineer should then be careful in the replacement and examination to discover the cause of this compression loss.

While most engineers fail to run a center line through the shaft main bearings it is advisable to do so. All that

is necessary is to pass a line through the several bearings and see that the line just touches the lower part of each bearing. If extreme accuracy is desired, the line may be run through the center of the bearings. By putting a stick at each outer bearing and by measuring the distance between the wire and several bearings, any low bearing can be found at once.

Broadly speaking, the engine frame never shifts so that any low bearing is traceable to wear of the babbit. This being true and since the housings for the bearings are all bored in line, it is actually merely necessary to measure the thickness of the bearing shell by a micrometer. If a bearing measures less in thickness than the others this one is low. To bring the several bearings in line it is necessary to scrape the other bearings until they are as thin as the low one. This brings all in line.

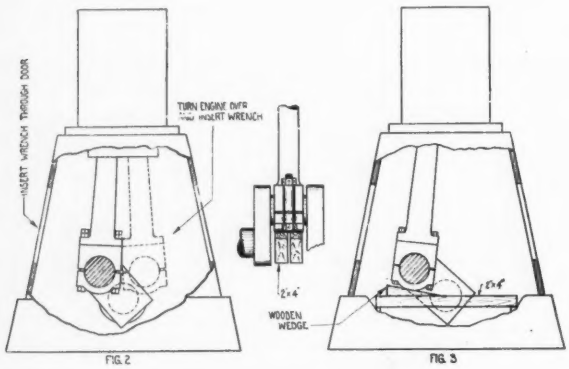


FIG. 2. END BOLTS MAY BE MADE ACCESSIBLE BY BARRING OVER ENGINE

FIG. 3. BLOCKING IS USED TO SUPPORT BEARING WHEN CONNECTING ROD IS REMOVED

If the oil grooves in a bearing prove to be stopped up, a new groove should be cut in it. This groove should be in the form of a cross, but the legs should not reach the outer edges. The shaft journals are seldom scored. If scores or grooves are present, these, if small, can be stoned out by using an oil stone. If bad, the shaft should be sent to a machine shop and the journals re-turned. Grooves, when circular, are not dangerous as they soon wear the babbit to shape and many shafts are in service having badly grooved journals.

The crankshaft can now be replaced, and the bearing caps readjusted. It is necessary to see that the clearance between the caps and shaft is not too great. If a large clearance exists, the tendency of the shaft to whip may cause severe pounding. To check the clearance, shims of a thickness the engineer thinks about right are placed on the sides of the lower bearing edge; two leads are placed about the shaft top as in Fig. 4, and the cap drawn down until the edges grip the shims. Upon removing the bearing cap, the leads are measured. If thicker than the desired clearance which should be about 0.001 in. per in. of shaft diameter, enough of the shims should be removed to bring the clearance to normal.

With the shaft in place attention is turned toward the crankpin bearings. These usually are the ones that show the most wear, for the severest duty falls upon them. The babbit in many instances is worn slightly oval and must be scraped to a fit upon the pin.

In scraping, the top half of the bearing should be treated first. A light coat of Prussian blue or lampblack mixed with oil is coated lightly over the top half of the crankpin. The bearing half is then placed on the pin and given a slight rotating motion as shown in Fig. 5. Upon removing the bearing, the high points in the babbit are found covered with the lampblack. A scraper is used to remove the coloring along with a light skin of the babbit under the spots. The pin is again colored and the bearing replaced and rotated. Upon the removal, a greater number of spots are found covered and the scraper is put into play again to remove these spots. This process is kept up until the lampblack covers the entire babbit along the lower two-thirds of the shell, while the babbit close to the parting should be cut away or chamfered to allow the oil to wedge in and form a film.

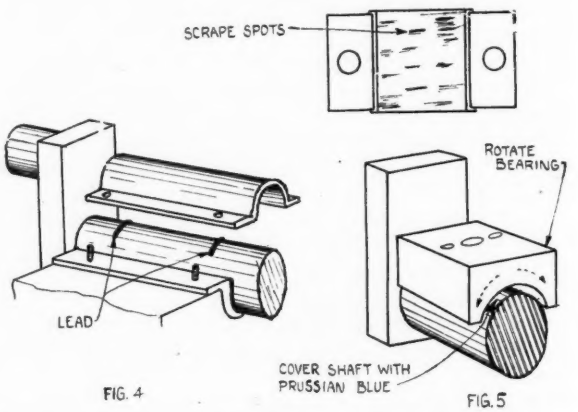


FIG. 4. LEAD STRIPS ARE USED IN DETERMINING BEARING CLEARANCE

FIG. 5. BEARINGS ARE SCRAPED IN BY USING PRUSSIAN BLUE TO INDICATE LIGHT SPOTS

It is quite necessary that the distance between the connecting rod face of the bearing and the babbit surface a and b (Fig. 6) be equal. In other words the axis of the bearing and the axis of the shaft must be parallel. If not the bearing will be cocked a trifle and this will put the rod out of line as shown. If this is not corrected, the rod will throw the crank bearing sideways at each revolution and the bearing will bell or become larger at the ends than at the center. As a result, the piston will bear against the sides of the cylinder, wearing it oval. Many Diesel engines show that they are troubled this way, by the side travel of the crank-shaft. Usually the operator doesn't know what is wrong. A pair of calipers or micrometers should be used in checking the bearing thickness to eliminate this trouble.

After the crank bearings, attention is turned to the piston-pin bearing. This bearing wears but little. A small amount of scraping will be all that is needed.

In giving this bearing the correct amount of clearance the pin should be removed from the piston and placed on the lower part of the bearing. Two leads should be laid across the pin and the top half of the bearing set in place and the bolts drawn up until the two bearings touch. Upon removal the clearance is measured and brought to the right value, about 0.006 in. by putting in or taking out shims.

The piston will need in all probability nothing outside of cleaning the ring grooves. These, especially the two upper ones will be gummed to some extent. To remove the gum, the piston should be set in a wooden tube filled with lye water. The lye will eat the gum and make it so that a brass scraper will take it off. Always use a brass and not a steel scraper for the steel will roughen the groove.

Rings will need cleaning and the two upper rings should be replaced by new ones. The life of a ring should be about 2 yr. The piston should be examined for grooving or flat spots. If but small in extent, the flat or groove is not dangerous, but does, as a rule, indicate too small an amount of lubrication.

In replacing rings one should be careful not to expand them too much in springing them over the piston. The bottom ring should be first slipped over the head and forced down. When the top groove is reached the ring should be cocked a little so it will ride over the groove, see Fig. 7. The same method is followed as each groove is reached.

As the work progresses the air and admission valves should be taken apart and cleaned as the overhauling has

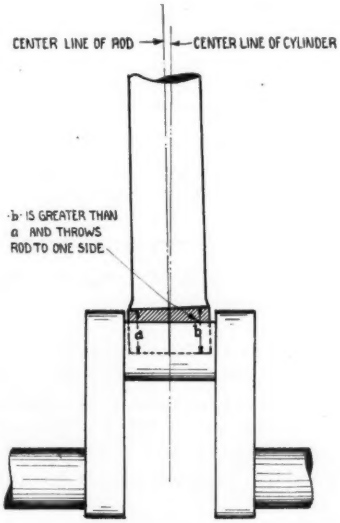


FIG. 6. AXIS OF BEARING AND AXIS OF CRANKSHAFT MUST BE PARALLEL

progressed. Kerosene will clean both cage and valve. Even though the seat looks to be in good condition, it is best to regrind the valve as a precaution. This is started with coarse or medium grinding compound, Clover Leaf brand is best, and finished with extra fine compound. Although many ignore it, the cage should be ground to a seat in the head.

The fuel valve should be taken apart and the needle ground to its seat. Only extra fine compound should be used for the smallest grit particle will score the seat. It is easy to see the condition of the needle tip, but the seat in the fuel valve body is hard to see. Often it is scored and the engineer puts the valve into service and wonders why the cylinder pounded.

To find the condition of the seat, a candle should be tapered at an angle of 60 deg. The tip is warmed just enough to soften it and the candle is inserted into the fuel valve housing and held against the seat for a minute or so. Upon removal the candle tip will show every minute score that exists on the seat. To remove a score or cut a reamer, which all builders supply, must be used. In making the cut, however, the reamer should not be forced or else the teeth or blades will chatter.

If the needle stem is rough at the point where it passes through the packing, this is due to sulphur in the oil. If not bad, the stem can be polished with emery paper; but, if quite rough, a new needle valve should be used. The gland packing should not be squeezed very tight, but just enough to prevent oil leakage.

In replacing the cylinder heads, a new gasket should be used for it is seldom the old one holds where used the

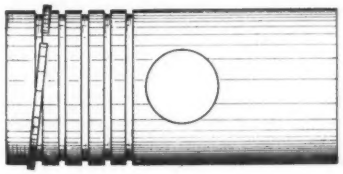


FIG. 7. TIPPING THE RINGS MAKES WORK OF INSTALLATION EASIER

second time. After putting the head in place, the stud nuts are run down and drawn up tight by striking the wrench with a sledge.

After cleaning the several valves and cages are then set in the head. In tightening the holding down studs, a sledge should not be used or else the cage may be warped and will cause the valve to leak.

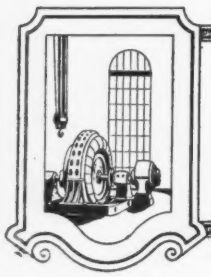
The fuel pump should be taken apart, cleaned and examined. As a rule, nothing need be done but to grind the valves.

Examination of the camshaft gears will show whether these are worn and whether they must be replaced. Usually it is the skew gears at the top of the governor shaft that wear, for there is considerable pressure on the teeth when a cam opens an exhaust valve against pressure. As example, an 8-in. valve has an area of 50 sq. in. and the cylinder pressure when the valve opens is about 50 lb. In other words the pressure amounts to 2500 lb., and the reaction comes upon the gear teeth.

Since the air compressor is the heart of the engine, it deserves special attention. All the valves should be examined and reground. The cylinders should be cleaned and any worn piston rings replaced. The inter-cooler coils and cylinder jackets should be cleaned of scale. It is best to use muriatic acid, about half and half of water. This will cause the scale to soften and it will wash out.

The generator shaft should be alined with the engine shaft. If this short shaft has two bearings, its alinement is checked by measuring the faces of the couplings. If in line, the faces will check at all points. If the shaft has only an outboard bearing and the inner end is supported by the engine shaft, the alinement can be checked by raising the out-bearing until the shaft just leaves the engine bearing next the flywheel. The outboard bearing is then lowered until the shaft just touches the engine bearing.

These points cover most of the things to observe in overhauling an oil engine. It must be remembered, though, that each engine has peculiarities of its own, and the engineer must be governed accordingly.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Operation of A. C. Generating Equipment---I

FUNDAMENTAL CONSIDERATIONS WHICH SERVE AS A FOUNDATION FOR A PRACTICAL STUDY OF A. C. APPARATUS. BY V. E. JOHNSON

WHILE THIS ARTICLE is not primarily concerned with the general theory and mathematics of alternating currents, it is manifestly impossible to discuss the principles of the machinery involved without first establishing a foundation on which to build. Various mathematical relations must be given, and the meaning of the most common technical terms explained.

Consider a conductor passing by the fixed structure of an alternator, and subjected to the flux which flows from pole to pole. The potential set-up in it will reverse simultaneously with the change in the direction of the flux, and will be, say, positive under all of the north poles, and correspondingly negative under the south poles. There would be a reversal of potential between each pair—hence the number of alternations in a revolution would be equal to the number of poles. Figure 1 illustrates this. Furthermore, the arrangement and interconnection of the armature conductors would in no way change this principle.

In any mechanical or electrical operation "cycle" is a general term used to designate a completed series of related events that recur periodically. Thus in an engine, a cycle would consist of two strokes—one forward and one rearward. In a pendulum it would consist of two swings—one in each direction.

In the alternator, a cycle consists of two alternations—and includes the various events that occur between the time a conductor passes a given part of a field pole—until it passes the corresponding point on the next similar pole. We have said there are as many reversals of voltage in a conductor per revolution as there are field poles—and it follows that there are half as many cycles. In other words, when a conductor has passed a pair of poles it has gone through one cycle. Thus a 10-pole machine has five cycles per revolution, and if it revolved 720 times per minute—it would have $720 \times 5 = 3600$ cycles per minute or $3600 \div 60 = 60$ cycles per second. This applies to direct current ma-

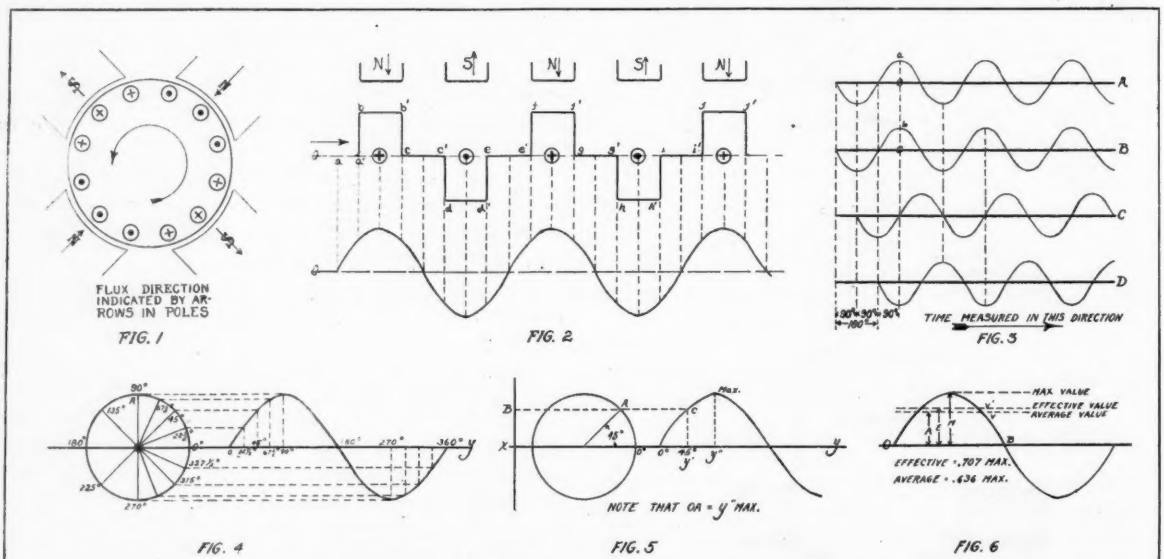


FIG. 1. DIAGRAM ILLUSTRATING DIRECTION OF INDUCED CURRENTS IN ARMATURE CONDUCTORS. THE DOT INDICATES AN UPWARD CURRENT WHILE THE CROSS REPRESENTS A DESCENDING CURRENT. FIG. 2. DEVELOPED FIELD STRUCTURE AND WAVE DIAGRAM. FIG. 3. DIAGRAM TO ILLUSTRATE MEANING OF PHASE DISPLACEMENT. FIG. 4. SHOWING METHOD OF DRAWING A SINE CURVE. FIG. 5. VECTOR DIAGRAM WITH PROJECTED SINE CURVE. FIG. 6. DIAGRAM ILLUSTRATING AVERAGE AND EFFECTIVE VALUES OF AN ALTERNATING CURRENT

chines also. For example—an eight-pole direct current generator running at 600 r.p.m. would have a generated frequency of $\frac{(8 \div 2) \times 600}{60} = 40$ cycles per second. The commutator would of course convert this into direct current by reversing it 80 times per second.

We have used the word "frequency" above, and without any further definition it is seen that it is a term used to designate the number of cycles in a given period of time—as "60 cycles per second," or "3600 cycles per minute." The second is the usual time unit used.

The term "phase" is one which occurs often, and which is more difficult to explain. Basically the word means "portion" or "part," but it is used in several different ways in electrical discussions, therefore it is likely to be but vaguely understood.

A three-phase generator is one in which the windings are divided into three major sections, each of which generates its portion of the voltage, and supplies its part of the load current. Similarly in a two-phase machine, the windings are divided into two parts. In general, an alternator having its windings so divided into two or more phases is called a "polyphase" or "many phased" machine. The voltages and currents in these polyphase machines bear certain relations to each other, and these are spoken of as "phase relations."

In order to represent the action of the voltage in a generator, a diagram as in Fig. 2 is used, where a "developed" field structure is shown in part, with a conductor passing in front of a number of the field poles—and having set up in it an alternating e.m.f. (electro-motive force). At the point a it is midway between two poles, cuts no flux and has no voltage generated in it. At a′ it comes into the flux of the first pole and has a voltage set up in the direction indicated by the cross—this being used to represent the tail of a descending arrow. The line bb′ is used to designate the value and direction of the generated voltage—the distance from the zero line indicating the value—and its location with reference to it—above or below, the direction.

Thus in front of all of the north poles, marked N, the voltage has a positive value, as indicated by the portions bb′, ff′ and jj′. This value is equal to the distance b′c or e′f. In front of the south poles, marked S, the voltage has a negative polarity as indicated by the portions dd′ and hh′. The value is equal to c′d or ed′. Inasmuch as the negative and positive loops are equal, b′c is equal to c′d. Between the poles, where the conductor cuts no flux, the voltage falls to zero, as indicated by the portions aa′, cc′, ee′, gg′ and ii′, all of which lie on the zero line.

Actually, the flux does not stop abruptly at the edge of the poles, nor is it uniform across the pole faces. Therefore the voltage curve is not made up of rectangular loops but rises to the various values gradually as in the lower curve in Fig. 3. The actual shape of the positive and negative voltage loops is determined by the design of the generator.

In Fig. 3 are shown four curves, the degrees being marked at the bottom of the diagram. These four curves have the same frequency, that is, the cycles are of equal length, but they do not rise and fall simultaneously.

A and B are "in phase"; that is, they have a displacement of zero degrees. Their positive and negative waves occur simultaneously, as do the points of zero value. It does not follow from this that the voltages represented by A and B are equal, as there is no relation between phase displacement and voltage values. Two voltages may be equal—and still be "out of phase"—and on the other hand they may be unequal and "in phase."

Curve C represents a voltage which is 90 deg. displaced from A and B. It will be seen that this curve has zero points at the same instant that A and B are at maximum positive and negative values.

Curve D is 180 deg. out of phase with A and B; i. e., it is in exact opposition. It is only 90 deg. displaced from C.

Phase displacement is also referred to as angular displacement, while the condition of being "out of phase" is also frequently referred to as being "out of step."

We have stated that the shape of the curve representing rise and fall of the voltage in an alternator as drawn in Fig. 2 is determined by the design of the machine. It follows that there are an infinite number of wave shapes—varying from extremely peaked to flat, and having various irregularities in their outlines; however, in electrical calculations it has been found convenient to assume that the waves are of the "sine" shape—this permitting the application of very simple mathematical principles to their solution. The simplest trigonometrical formulas can be applied and problems worked out graphically without much difficulty.

As a matter of fact, a great many practical machines approximate closely a true sine curve.

Representing Alternating Currents by Vectors

We can of course not discuss at length the various properties of a sine curve, but must confine ourselves to a brief description of it, and its generation. In a sense, a sine curve is graphic representation of a simple harmonic motion, which in turn is the motion which a point on the circumference of a rotation wheel has when viewed edgewise. This can be seen in Fig. 4. Here a line O-A rotates about a center (O) at a uniform speed. Along a horizontal line are laid off units of length, using any scale convenient. These units are marked "degrees"—starting at 0 deg. and going up to 360 deg. Similarly the circle made by the rotation of the line O-A is marked in degrees as indicated. Thus there are on the line a number of points which correspond to the markings on the circle. By drawing horizontal lines through the point A at the various angular positions which O-A occupies, to intersect vertical lines from the degree markings on the line, a number of points are established, through which a line as shown may be drawn. This line is a sine curve; obviously, any point on such a curve corresponds to a definite position of the revolving line or "vector" O-A. The distance from the horizontal zero line to this point is always the length of the line O-A projected on a vertical scale, the angle y O A in geometrical degrees being taken to correspond to the "linear" degrees (if we may use that term) laid off on the horizontal zero line or "x axis" as it is usually called.

If we take O-A of a length to represent the maximum value of a voltage wave—measured to any suitable

scale, we can find its value at any other instant by merely projecting O-A to a vertical axis, at the proper angle y O A. In Fig. 5 we have a maximum value O-A, and an instantaneous value X B at the line where the angle y O B is 45 deg. It corresponds to the voltage y'c on the curve in Fig. 5, which is the corresponding sine wave.

In dealing with electrical problems, it is customary to draw the vector only, and to omit the sine wave to which it is related.

So far we have spoken of maximum and instantaneous values, their meaning being self evident. There are two other expressions that we must consider in this connection; namely, "average value" and "effective value." In Fig. 6 is shown one cycle of a sine curve. If the curve is symmetrical, the average value throughout the cycle would be zero, inasmuch as the positive and negative loops are equal. However, for either loop the average value would be at the line a v, which equals the area of a loop divided by the distance O B. In a sine curve this average value is .636 of the maximum value, but in curves of other shapes there is no constant mathematical relation, this obviously being determined by the wave outline.

In this same Fig. 6 the line e v' represents the effective value which is the value a direct current would have to have in order to produce the same heating effect in a circuit. That is to say, an alternating current of effective A amperes would have the same heating effect as a direct current of A amperes. In a sine curve, this value is equal to .707 times the maximum value, but of course in waves of other shapes this ratio is different.

Alternating current instruments are calibrated to read in effective volts and amperes, and they are designed to read "up" regardless of the fact that current or voltage alternates.

In dealing with direct currents and voltages, it has been possible to add or subtract them by plain arithmetic. Thus two voltages in series, of values A and B, have a combined value of A + B. Similarly power is calculated by simple multiplication, and a circuit of A volts carrying B amperes has a power of AB watts or

$$\frac{AB}{1000} \text{ kilowatts.}$$

This is, however, not true in alternating currents except in special cases. In Fig. 3 are represented voltages out of phase by varying amounts. These figures could also be used to represent currents, or one curve in them could be voltage and the other current.

If two alternating voltages are to be added, the sum at any instant would equal the instantaneous values of the components added algebraically. Referring to Fig. 3, the voltages A and B added would at any instant equal the instantaneous sums of the instantaneous values as a-o and b-o. The resultant curve, if drawn, would have the same frequency as A or B, but would have wave loops of an amplitude, or height, equal to max A + max B. It would have a vector value equal to the sum of the two component vectors. But effective value of A = .707 × o a, effective value of B = .707 × o b, hence effective value of A + B = .707 × (o a + o b). In other words, two voltages in phase (i.e., having no angular difference between them), can be added by merely combining their values algebraically. Inasmuch as a phase displacement of 180 deg. is equivalent to reversing one of the components, it follows naturally that voltages in oppositions (displaced by 180 deg.) are added algebraically, which means nothing more or less than that they are added with reference to their polarity.

Thus if A = +100 v. and B = +200 v. (using measured effective values) then A + B = 300 v. effective. If A and B have the same values, as above, but are 180 deg. displaced, then A + B = 200 — 100 = 100. This is fairly obvious and does not require further consideration. It is also evident that if the lines o a and o b are drawn to represent the effective values of the voltage, instead of the maximum value, then their lengths added will at once give the effective value of the sum. "Effective" vectors do not rotate, but are added trigonometrically.

Wind Causes Meter Mystery

DRAFT CAUSED BY ROTATING MACHINE AFFECTS METER READING. BY W. B. DEMUTH

IN LOOKING for trouble with electrical machinery, it is best not to form a conclusion until you have analyzed the situation and eliminated the known variables. Bearing this fact in mind will often simplify the job of finding trouble and save valuable time.

Recently an unusual meter problem occurred where the problem appeared complex. Actually it was ridiculously simple, and it was not really an electrical problem at all. Much valuable time and a fairly large power bill would have been saved if this fact had been recognized at the start.

In the station where this incident occurred there were several large synchronous converters supplying direct current from an alternating current supply. Each machine was metered on both the direct and alternating current sides using an induction type meter for the high-voltage side and a watt-hour meter on the direct current side, these latter meters using the usual resistance and compensating coils.

Soon after the new machine had been started up it was discovered that the metering of the machine adjacent to it, which had been in service several years without trouble, was behaving erratically. The daily 24-hr. readings of alternating current input and direct current output did not agree, and the ratio of input to output varied from day to day. It should, of course, have been practically constant. Sometimes the ratio was correct and gave the commercial efficiency that was to be expected; at other times the alternating current input as given by the meter was too low, indicating higher machine efficiency than was probable.

Several times the meter was tested when hot and when cold, and the results compared with past calibrations. The meters did not run slow or were not sluggish; nor did either of them creep. Yet from day to day the registration was erratic. It was decided that the meters were to blame, since the efficiency of the machine would not vary from day to day to any appreciable extent.

Closer attention to the problem showed that the ratio of input to output of this one machine depended upon whether the machine adjacent to it, recently started up, was operating or not; and how long it did

operate. When the machine was not running at all during 24 hr., the input-output ratio of the other machine was apparently correct. When the new machine was running, however, the direct current output of the machine giving the trouble appeared too high in proportion to the alternating current input. Clearly then, there was some relation between the two machines or between their meters. Each machine tested clear in every way from the other. There were no crossed wires, grounds or other conditions to interfere with the meters. Magnetic fields and inductive disturbances could not be found. Lamping out the meter circuits showed everything as it should be.

Then it was discovered, almost by accident, that the draft produced by the rotation of the new machine created a pressure in the pit as the armature churned up the air, and this air found a ready outlet through a conduit that opened up at the resistance element of the direct current meter that was involved in the trouble. This cool breeze cooled off the resistance and caused the direct current meter to run faster than it should, so making the output and machine efficiency abnormally high. As the resistance was cooled off by the new machine, the meter speeded up, so creating the discrepancy. Stopping this current of air by plugging up the conduit solved the problem.

Pointers on Winding Induction Motors

PRACTICAL NOTES ON ARMATURE WINDING FOR THE ENGINEER WHO REWINDS HIS OWN MOTORS. BY M. SANDFIELD*

ARMATURE winding is the art of assembling coils and insulating materials in the stationary and rotating parts of electrical machines; and of connecting them into circuits ready for operation. The skill of a winder is rated according to his ability to accomplish this with the least possible lowering of the insulating qualities of the materials he uses.

There are certain tools which are essential to the successful winding of any type of machine. In addition to these, certain types of winding require tools which have been especially developed to meet the specific needs. An experienced armature winder will in some cases develop his own tools, or modify them to meet his personal requirements. The tools illustrated in Fig. 1 are, however, sufficient for most winding of alternating-current stators.

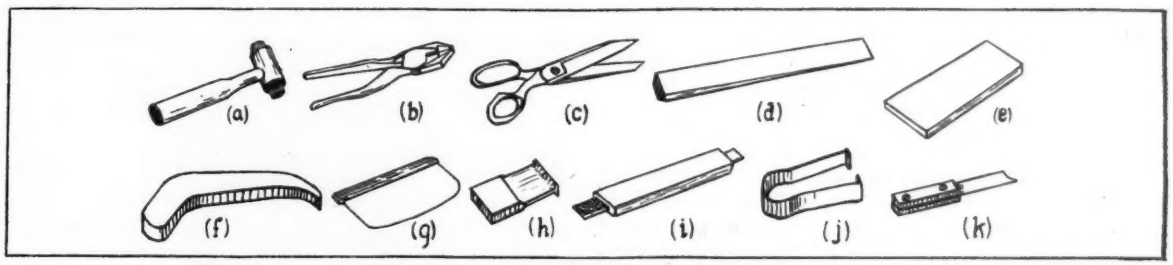


FIG. 1. TOOLS FOR WINDING INDUCTION MOTORS

(a) Rawhide mallet; (b) pliers; (c) scissors; (d) steel winding drift; (e) assorted thicknesses of fiber slot drifts; (f) fiber shaping drift; (g) fiber cell drift; (h) steel T-shaped cell drift; (i) wedge driver; (j) lead scraper; (k) knife.

OPERATIONS PRELIMINARY TO WINDING

1—The coil and insulating materials comprising the windings that go into a slot are usually so proportioned that they completely fill the slots. Hence if any foreign substances were to remain lodged in the slot at the time of winding, it would not leave room for the coil, and an attempt to drive the coil home would probably result disastrously. Therefore, the first step in winding should be a detailed inspection of each slot for foreign substances and irregularities of punchings.

2—Blow all dirt out of the slots with compressed air.

3—Examine the core on both faces for flared out punchings or retaining fingers. If any are found, drive them back until the core is even and straight on both sides.

4—By the location of the terminal block, determine on which side of the core the coil leads should be wound.

5—Mark the slots (top and bottom) indicating the proper throw for the first coil.

6—If the grouping is irregular, mark all the slots into which the bottoms of the phase coils are to be placed.

7—The windings should always make a tight fit in the slots. In cases where the coil with the customary slot insulation does not make a tight fit, side fillers, bottom fillers or spacing pieces of insulating materials must be used. In order to determine the exact amount of filler needed, try the winding out in one slot. All filler needed in depth should be placed in the bottom of the slot, or between the top and bottom parts of the coils, in order to bring the winding as near to the bore as possible.

From this point on the procedure will vary, depending on whether the stator has open slots or partially closed slots.

OPEN-SLOT WINDING

Coils for an open-slot winding usually are fully insulated and treated with varnish before winding. They are of two kinds—phase coils and plain coils. The phase coils differ from the plain ones only in that they are more heavily insulated on the ends to withstand the voltage between groups, which is much higher than the voltage between coils. They are usually taped with colored tape or otherwise marked to distinguish them from the plain coils.

* General foreman of winding, Westinghouse Electric & Mfg. Co.

Coils which have been fully insulated and treated before winding are rather delicate and are likely to have their insulating qualities impaired or broken down completely by careless or rough handling, or by unskilled workmanship. Such coils are heavily insulated on their straight parts, that is, on those parts of the coil that are put into the slot. This insulation furthermore is of such nature that it will not stand being disturbed either by bending, pounding or abrasion. The insulation on the coil ends is more pliable and will stand a reasonable amount of bending

For best results, therefore, the coils must be assembled into the slots without excessive pounding; without scrap-

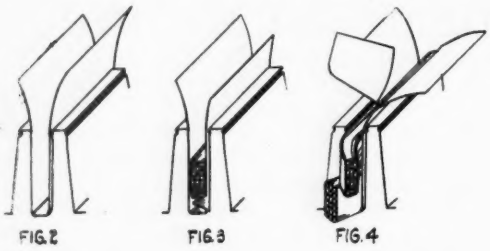


FIG. 2. OPEN SLOT WITH FISH-PAPER CELL IN PLACE
FIG. 3. THE WINDING CELL MUST NOT BE ALLOWED TO BUCKLE AS SHOWN
FIG. 4. TRIMMING THE SLOT CELL

ing the coils against the slots; and without bending their straight parts. To avoid the first, regulate the tightness of the coils in the slot to a nice driving fit by means of fillers—a coil which is too loose is almost as undesirable as one which is too tight, as any movement of the coil in the slot during operation will inevitably weaken the insulation.

To prevent scraping the coil against the rough sides of the slot, use a thin fish-paper winding cell, as shown in Fig. 2. Rub paraffine on the inside of this winding cell, and also on the coil. This will act as a lubricant and enable the coil to slide into the slot without damage. Such winding cells must be sufficiently thick to take up irregularities in the slot and of rather stiff material. They must be placed in the slot directly against the iron and not inside of the filler, so that the friction between the cell and the wall of the slot will be greater than the friction between the cell and the coil. Otherwise the cell would not stand up, but would go down with the coil as shown in Fig. 3, and crumple up in the bottom of the slot, taking up room that has not been allowed for.

To guard against the bending of the straight part of the coil, avoid driving the coil into the slot with the face of the mallet directly. Always use a fiber winding drift of the appropriate length and width over the coil to distribute the blow.

Start the coil into the slot with the straight part equally spaced on each side of the core. If the coil fits properly, it cannot be moved lengthwise in the slot after it has been driven to the bottom. Equal spacing on both ends of the core is essential because the heavy insulation ends at the first bend; and if the extensions of the straight part of the coil at the ends of the slot are not equal, the insulation may break down to ground on the short side.

After the slots into which the phase coils and the first coil are to be wound have been marked off, and after proper fillers have been determined to give the correct winding fit, proceed by inserting the winding cell and fillers into the slot into which the bottom or shorter straight part of the first coil is to go. Get the first coil started into the top of the slot with the lead towards the proper side of the frame, then drive it down to the bottom part of the slot by means of the fiber slot drift and mallet. Enter the top part of the first coil into its proper slot but do not drive it down, because it will have to be raised up later in order to put in the last coils. All the first coils whose top parts go into slots temporarily are called "throw coils" and their number equals the throw of the winding minus one. For example, if the throw of the winding is 1 to 10, there will be 9 coils in the throw.

Having completed the throw, proceed with winding plain and phase coils in the order indicated by the layout, until the first throw coil from the other way is reached. Then raise the upper parts of all the throw coils out of the slot just high enough to enable the last coils to be inserted. Raising them too high is liable to injure the coils.

After all coils are wound, drive them down tightly in the slots with a fiber slot drift and mallet and trim off the

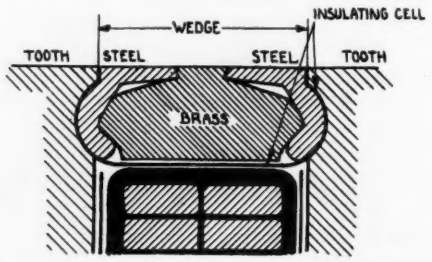


FIG. 5. CROSS SECTION THROUGH A MAGNETIC WEDGE

projecting parts of the winding cell with a knife, as shown in Fig. 4. Care must be taken that the coils are not injured in this operation. If there is room in the slot the cells may be trimmed high enough to permit folding them over the coil; otherwise they should be trimmed even with the bottom of the wedge grooves. The winding is now ready for wedging. This is best done with a wedge driver. If the iron section is wider than 6 in., two or more wedges are used per slot. For best results the wedges should be chamfered at the lower entering end to prevent damaging the coils. They should not project more than $\frac{3}{8}$ in. out of the slot, as a longer projection is likely to curl up and rap on the rotor.

The winding must now be tested for soundness of insulation between phases and to ground. This is done by scraping the insulation from the ends of all the coil leads and connecting all the coils in each phase together with bare copper wire. Care should be exercised that no lead touches the frame or bridges across between phases. Then touch the terminals of the testing transformer to any two phases simultaneously, repeating these tests until all phases have been tested to one another. Then touch the testing terminals to each phase and ground simultaneously.

Metal Wedges

In case magnetic wedges are used, certain precautions are necessary. These wedges consist of two strips of steel.

held in place at the top of the slot by a strip of brass. The steel parts lie in the wedge grooves and the brass part in a recess formed by the two steel pieces as shown in Fig. 5. The whole is insulated from the punchings by a thickness of fish paper. The grooves which are to receive the metal wedges must be straightened—not filed—until smooth and even, and the winding must lie in the slots solidly and low enough to permit the insertion of the wedges.

Up to seven inches width of iron, the steel part of the wedge is of one piece, bent into the shape of a hair pin, and spread with a single piece of brass. For wider iron, two separate steel wedge pieces are used, one for each side. The steel parts should extend about ¼ in. beyond the side of the slot on each end. Two brass spreaders are used whose combined length equals the width of the core, and these are driven in from opposite sides.

Before inserting the wedges, apply a coating of heavy shellac to the grooves and insert a piece of fish paper so folded that it will cover the top of the winding, extend into each groove and project above the top of the slot about ½ in. Insert the steel wedge into the fish-paper cell and with a knife or screwdriver spread it open enough on one end to start the brass piece. The latter is then driven with a wedge driver until its end is even with ends of the steel; a commutator punch or special tool is then used to drive the brass even with the edge of the core. Wedge every other slot, keeping the eyes of the hair pin, if the steel is in one piece, on the same side of the yoke. After half the slots are filled in this way, begin wedging the remaining slots by placing the steel wedges with the eyelets on the opposite side of the core. When the first wedge in the second round has been driven, it can be tested for tightness, as the wedges on either side will prevent the teeth from bending. This is done by placing a finger across the slot, so that it covers not only the wedge in that slot but also the tooth on either side. Then strike a gentle blow on the wedge with the peen of a riveting hammer or similar tool. A jar indicates looseness, which is remedied by removing the wedge and using heavier fish paper or a double thickness of fish paper for insulation in all slots yet to be wedged.

After the proper thickness of paper has been determined, proceed to fill the remaining slots until the wedging is completed. The brass parts of the wedges are then even with the edge of the core, while the steel parts extend beyond both the core and the brass. This extension should be nicked or clinched to prevent the brass pieces from backing out. If the brass is in two pieces, they should be soldered together in the middle, thus completing the operation. The fish paper that extends out of the slot into the bore is now trimmed even with the wedge with the rounded end of a knife. The wedges are then ready for testing for their insulation from the iron. This is done by means of a 110-v. test circuit with a lamp in series, holding the terminals of one line on the iron and the other on the wedge.

Partially-Closed Slot Winding

Coils for this class of winding are usually uninsulated, except for the cotton covering on the individual wires. They are all of one kind when they come to the winder, that is there is no difference between plain and phase coils, as in the case of the open slot windings but according to the service requirements.

In a two coil per slot winding with partially closed slots, the coils are wound or pulled to finished shape, their individual turns being held together by bands of light but strong twine. These bands are placed at the points where the leads leave the coil, and thus serve the additional purpose of anchoring the leads to the coil.

As the coils in a winding of this type are uninsulated at the start, the insulation to ground is applied to the slot in the form of a winding cell, which lines the slot completely with the exception of a narrow opening corresponding to the opening in the slot.

Slots into which the first coil is to be placed should be marked for both top and bottom sides. Also all slots that are to take the bottom parts of coils that are to be the beginnings and endings of groups should be marked. Cells should then be placed in all slots.

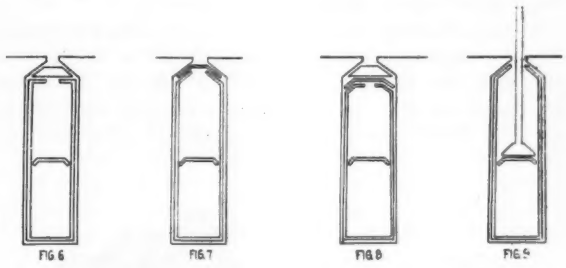


FIG. 6. LIPPED CELL AND STRAIGHT WEDGE
FIG. 7. LIPPED WEDGE
FIG. 8. BOTH LIPPED AND STRAIGHT WEDGES
FIG. 9. USE OF T DRIFT

Next take the throw coils (in number one less than the throw of the winding) and apply a temporary taping on the whole upper half, from the leads to the opposite extremity of the coil. With the leads toward the proper side of the frame, proceed threading the lower parts of the throw coils into the slots, the upper parts remaining in the bore to the last, being protected against damage by the temporary taping. The threading of coils into the slot is done one wire at a time, the first one being threaded through completely before starting on the second. This tends to keep the wires from crossing one another. Avoid bends and nicks as they take up slot room, while crossed wires may result in short-circuits. To make the wires slide past one another readily, rub the coils with paraffine.

When the lower half of the coil is in the slot and the coil properly located with respect to the extension on both ends, insert the center strip, which should be slightly longer than the cell. It is important that this strip shall properly separate the two coils in the slot. It should be as good an insulator as the insulation used between phases—usually being of the same material as the slot cell. This center strip is tapped home with a T-drift. To keep the winding and center strip from getting out of place during further manipulation, insert a temporary wooden filling piece large enough to fill the rest of the slot. Depending upon the design, the portion of the coil outside of the slot is now taped before proceeding with the next one; or else left untaped and triangular pieces of treated cloth inserted between adjacent coils and groups as they are wound.

The first coil, after the throw coils, is threaded into both the top and bottom of the respective slots. The top is inserted by taking out the temporary filling piece and

threading the wires into the slot as before, except that the spring in the wires already in the slot may necessitate an occasional tapping down with the T-drift, or packing the last wires with the fiber cell drift.

When all the wires are in place, close the slot by one of the methods shown in Figs. 6, 7 or 8 according to the design, making sure that a seal has been established between the cell and the wedge. Flat wedges are driven with the ordinary wedge driver as shown in Fig. 1 (i). Lipped wedges are best driven with a specially shaped wedge driver, shown in Fig. 10. The rest of the coils are then inserted, wedging and insulating them until the throw coils are reached. These are raised to clear the slots underneath them sufficiently to permit inserting the lower parts of the remaining coils. The temporary tape is then removed from the throw coils and they are threaded one by one into the tops of their respective slots.

If the coils or groups are separated by insulating pieces, after the winding is completed, these should be trimmed off even with the winding, as shown in Fig. 4. Then tap down with the drift or mallet any wires that may not lie in place. Make sure that the winding clears the bore and

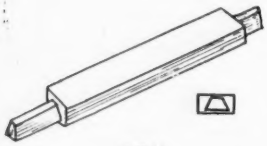


FIG. 10

FIG. 11

FIG. 10. WEDGE DRIVER FOR LIPPED WEDGES
FIG. 11. THE STUB OR CONNECTION BETWEEN ADJACENT COILS

the bracket. Test for grounds and short-circuits between phases in the same manner as described for open-slot windings. After connecting, the stator is ready for treatment in varnish and baking.

Connecting

Connecting operations may be considered as consisting of three steps.

1—Stubbing the groups.
2—The connecting proper.
3—The placing and securing of terminal leads.

Each group starts and terminates with a phase coil. The stubbing operation consists of connecting all the coils of a group in series—the outer lead of each coil connecting to the inner lead of the adjacent coil. The connection between the two is the stub. The length of the stub, that is the distance it is permitted to extend away from the coil, is determined by the clearance to the bracket. The stub is made by scraping the wires clean with the scraper shown in Fig. 1 (j) and fastening the inside lead of one coil to the outside lead of the adjacent coil by means of a copper sleeve connector, as shown in Fig. 11. A suitable flux is then applied and the stub soldered, preferably by pouring molten solder over it.

A group thus connected will form a continuous circuit, beginning with the outer lead of one phase coil and terminating with the inner lead of the other. The cross connections and terminal leads are connected to the group ends in accordance with the connection diagram, using lap joints which are held together either by sleeve connectors or by the wrapping of turns of small bare copper wire around the joints, which are soldered the same as the stubs. The stubs and connection joints should be freed from burrs, and then thoroughly insulated according to the voltage with treated cloth tape held in place with cotton or friction tape.

Connecting wires and lead cables should then be laid down as nearly parallel to one another as possible on the outside of the end winding, being careful that ample clearance to the end bracket is provided. They should be tied in place by strong, light string. The terminal leads are then brought out of the frame and cleated in place. They should be protected with insulating tubes where they are fastened into the cleat.

On testing the winding for rigidity on its front and rear extensions, it will be found that the connections between adjacent coils and groups have a bracing effect on the front end which the rear end lacks. To secure this part of the winding against vibration it is braced, in ordinary industrial motors, by tying each coil securely to a heavily insulated steel ring. All exposed parts of the winding can now be painted or sprayed with an air drying finishing varnish.—The Electric Journal.

Grease Balls

By W. F. Schaphorst

IT WAS brought to my attention sometime ago that "grease balls" sometimes form in boilers. They are spherical in shape and have actually been known to assume proportions the size of a league baseball—up to 3 in. in diameter. These balls form from the precipitated solid matter that is too often permitted to pass into the boilers with the feed water. This solid matter combines with the grease that also sometimes accompanies feed water, usually forming a ball the size of a small pebble or a trifle larger. The 3-in. sizes are unusual. When these balls touch the boiler shell, they are liable to stick, insulate the shell, cause undue heating, and as all engineers know, the boiler may bag or burst as a result. The best remedy for this, of course, is to keep grease out of the boilers by means of separators and extractors, and to precipitate the solids outside of the boiler.

Feed water problems are much better understood now than ever before and there is little excuse for permitting grease or any scaling or solid substance inside of a boiler shell. Don't go ahead and use a certain water without knowing what it contains. Send it to a "feed water doctor." In this connection, it may interest readers to know that in the building of condensers our manufacturers are nowadays testing the water that is to be used for cooling purposes before making the tubes in order that corrosion-resisting tubes will be provided in the condensers. The tubes are usually made of brass, yes, but even such tubes are subject to corrosion and in some localities must be renewed every year even after being made in the most scientific manner known to man.

Correction Note

Attention is called to the omission of water circulating tubes in Fig. 22, page 14 of the Jan. 1 issue. This cut shows the Ladd through-drum boiler, which is built with a single row of water circulating tubes tying in the two upper drums.

THE INQUIRING ENGINEER

The Inquiry

There seems to be some difference of opinion among power plant engineers as to the relative merits of stage feed water heating and auxiliary exhaust heating as employed in central stations. What factors must be taken into consideration in determining which system shall be used in any given instance? Under what conditions will one system show a greater over-all economy than the others? Is it purely a question of efficiency in the station heat balance or are such considerations as cost and reliability paramount?

Replies

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Day & Zimmermann, Inc., Philadelphia, Pa.

There is no question but that the method of heating feed water by means of bleeding steam at one or more points from the main turbine unit is more economical from a thermodynamic standpoint than the older method of heating the feed water by the use of exhaust steam obtained from steam driven power plant auxiliaries. The use of stage feed water heaters and turbine bleeding introduce complications in the arrangement of piping and heaters adjacent to the main turbine unit but this is more than counterbalanced by the omission of extensive piping, which, would otherwise be required to carry steam to and from the steam driven auxiliaries. To a certain extent the stage feed water heating complicates the operation but probably this is not absolutely true but only relatively so because the average power plant operator is more familiar with the older steam driven auxiliary apparatus. Another feature, which, is sometimes troublesome is the difficulty of maintaining a constant feed water temperature by bleeding steam from the main units with a variable load on the main turbine. The tendency in the more recent installations utilizing stage feed water heating is to forget the old idea of maintaining a constant feed water temperature and permit this temperature to vary in accordance with the pressures, which, automatically occur at each of the bleeding points on the main unit with variable load.

Logical design of a station in which the feed water is heated entirely by bleeding steam from the main unit is to have all of the auxiliaries driven by motors supplied by energy from the main station bus. Such an arrangement, however, is seldom satisfactory from a standpoint of reliability. It is particularly desirable to have the condenser circulating pumps and boiler feed and house service pumps driven from a source which cannot be affected by any possible interruptions due to trouble with the main station bus. To obtain this reliability, there are two methods available:

First—To install dual drive units in which an auxiliary turbine is installed on the various units which it is desirable to maintain in service under all conditions and so arranged that the unit is driven by the motor under normal operation conditions and the steam turbine held in reserve to take the load automatically in case of failure of energy supply to the motor.

Second—To install a house turbo-generator so arranged that it will produce electrical energy for a part or all of the motor driven auxiliaries. Sometimes this house turbo-generator is connected with the main bus through protective devices so that it will automatically be disconnected in case of trouble with the main bus, thus leaving the energy supply to the auxiliaries in operation during times of trouble on the main bus. This house turbine may be operated as a straight condensing unit or its exhaust may be used to heat the feed water in either a surface condenser or in a jet condenser. In case the exhaust from the house turbine is used to heat the feed water, the amount of steam which it is possible to bleed from the main unit will be greatly decreased and consequently the thermal efficiency of the plant as a whole will be reduced due to the lower efficiency of the smaller house turbine. In a great many cases, however, the necessity for reliability of service of the auxiliaries warrants the slight decrease in thermal efficiency, which, results from the use of the house turbine. It has recently been proposed to install an emergency house turbine so arranged that it will automatically assume the electrical load required by the necessary auxiliaries whenever there is an interruption of energy supply from the main bus. In this case the full advantage may be taken of the thermal gains due to stage bleeding for feed water heating. However, the fixed charges on the investment involved in a complete stage feed water heater system plus an emergency house turbine generator must be carefully balanced against the difference in thermal efficiency between the straight bleeder heating and the use of exhaust steam from the house turbine for feed water heating.

In other words, the thermal efficiencies involved in the various methods of heating feed water are subject to definite calculations but, in addition, the decision for any individual plant must be made by considering also the relative fixed charges and particularly the degree of reliability of auxiliary drive which is necessary in the opinion of the designing engineer.

W. J. RISLEY, JR
Curtis Publishing Co., Philadelphia, Pa.

Any discussion of the relative merits of stage heating of boiler feed-water by extraction from the main unit, and

of heating from the exhaust of station auxiliary units, must consider three questions: Efficiency, costs, and reliability.

1. EFFICIENCY. It is unquestionably more efficient to heat the feed-water by bleeding the main turbine, and drive all the auxiliaries with motors running on main unit current. The principle involved here is the extraction of the maximum amount of power from the steam before it is used for heating purposes.

If we heat the feed water with the auxiliaries exhaust, we have only a single-stage heating. Assume live steam at 250 lb. gage and 200 deg. superheat, the total heat per lb. of steam at this point being 1315 B.t.u. Assume the auxiliary turbine to be 100 per cent efficient, and that it exhausts saturated steam at 1 lb. gage to the feed heater. The total heat at this condition is 1150 B.t.u., showing that 165 B.t.u. has been converted into power.

If, instead, we do the same heating in say three stages by bleeding the main unit, we will have available for conversion into power 165 B.t.u. per lb. from a portion of the heating steam, about 210 B.t.u. from another portion, and about 250 B.t.u. from the balance. This gives an average of about 210 B.t.u. per lb. available for conversion into electrical energy, as compared with 165 B.t.u. for auxiliary exhaust heating. The fact that the auxiliary turbine is far less efficient as a power producer than the main unit makes the spread even wider.

It has been shown that a drop of about one per cent in the total heat requirements of the plant will result from replacing a boiler feed pump turbine with a motor, and bleeding the necessary feed heating steam from the main unit. Motorizing the other auxiliaries would increase this saving proportionately.

Another disadvantage inherent in auxiliary exhaust heating is the fact that the supply of such steam is practically constant over a wide range of station load fluctuation, whereas the demand for feed-water varies with the load. This results in alternate excesses and deficiencies in the steam supply to the heater. The excess steam goes to waste, and the deficiencies cause low feed temperatures and high oxygen content in the water unless live steam is admitted.

The only economical method of getting away from these losses is to have a duplex drive on one of the large auxiliaries, such as a circulating pump. Then the load on this auxiliary will be shifted back and forth between the turbine and the motor in accordance with the demand for steam in the feed heater.

If, then, we consider efficiency alone, the palm goes to stage heating by bleeding the main unit; and the more stages, the more efficient the heating becomes.

2. COSTS. We have just concluded that a seven-stage heating, for example, would be more efficient than a two-stage. But we must keep in mind that if we heat the water in seven stages, we would have to buy a series of seven feed-water heaters. They would occupy valuable space; they would require expensive maintenance and high operating costs; and they would carry a heavy burden in interest and depreciation charges, to say nothing of a contingent obsolescence charge hanging over their heads.

Two-stage heating is so much more efficient than single-stage that the second heater is readily warranted. The increase in efficiency for the third stage will usually make the third heater a paying proposition, especially if operating pressure and superheat are high. But as we add each stage, our gain in efficiency is becoming smaller, so that by the time we get to the fourth stage, it may cost us $1.20 to save $1.00. For the seventh stage, it might cost us $2.50 to save $0.50.

If we bear these principles in mind, we still find that on the basis of ultimate economy stage heating by extraction is preferable.

3. RELIABILITY. We have listed reliability last; it should really be placed first, because the greatest obligation of a central station is reliability. Some stations are designed with this in view, and it is felt that some little economy can well be sacrificed; the difference is an insurance that the service will not be interrupted. Other stations prefer to design for the greatest economy, and take a chance that luck will be with them. The choice is entirely a matter of company policy.

It is in the matter of reliability that stage heating by extraction meets its greatest objection. Whatever may happen to the rest of the plant, the auxiliaries must be kept in operation; and the turbine is a surer drive for these auxiliaries than is a motor running on main unit current. The main unit may go down, and if it does, the motor-driven auxiliaries stop. But outside influences, such as electrical storms, etc., have no effect on the steam turbines driving the essential auxiliaries. The installation of turbines as emergency drives only partially solves this problem.

We have, then, the two points, efficiency and costs, strongly in favor of stage heating, while lack of complete reliability is the only drawback.

E. H. TENNEY, Chief Engineer of Power Plants, Union Electric Light and Power Co., St. Louis, Mo.

Any consideration of the relative merits of stage feed water heating and auxiliary exhaust feed water heating in central stations, must involve a detailed study of thermal and commercial economies in the use of (1) bleeder heaters; (2) house turbines for supplying energy for motor driven auxiliaries; (3) steam driven auxiliaries; (4) economizers; as well as other possible means of recovering heat that would otherwise be lost in the production cycle.

That the feed water must be heated is a foregone conclusion. If heat from auxiliary exhausts is not available, due to the use of house turbines and motor driven auxiliaries, then this heat for feed water heating must be supplied from another source. The fact that this heat may be extracted from the stages of the main generating units at a thermal advantage, seems to solve the problem in-so-far as lack of steam supply due to motor driven auxiliaries is concerned. This thermal advantage, which seems to be in the neighborhood of from 2½ to 3 per cent, makes bleeder heating preferable to utilizing the exhaust from house turbines, or other auxiliaries, to any greater extent than is necessary to complete the bringing of the feed water temperature up to the desired point.

Supplementary heating of feed water by the use of economizers is unquestionably justified from the standpoint of thermal economy, but from the commercial aspect this may be offset by fixed and maintenance charges, depending upon the value of the fuel saved.

GEORGE P. ROUX, Consulting Engineer, Philadelphia, Pa.

From the standpoint of heat consumption, the superiority of stage bleeding admits of no question, especially if

more than one stage is bled. The best small turbines obtainable utilize a relatively small fraction of the available heat range; thus, if steam is taken at the initial conditions common in present practice and exhausted at slightly above atmospheric pressure, the temperature of the exhaust steam is from 300 to 400 deg. F. This steam is ordinarily used to heat condensate varying from 70 to 120 deg., up to 212 deg. Such a heat transfer is fundamentally wasteful because of the wide temperature difference between the media during the process, and because the steam could have yielded much more work at a small sacrifice of its availability for feed water heating.

On the other hand, the main turbine absorbs much more of the heat available; so that even if only the stage giving a pressure corresponding to the auxiliary exhaust pressure is bled, the temperature of the bled steam is much lower, and the heat transfer correspondingly more efficient.

With single stage bleeding, there still remains the rather large temperature difference between bled steam at slightly above 212 deg. and condensate at 70 to 120 deg. As the number of stages bled is increased, the range of water temperature in each heater is decreased, as is also the temperature difference between entering steam and entering water.

By sufficient sub-division of the heating process, it is possible to approach as closely as is desired to the thermodynamic ideal of heat transfer at constant temperature.

The real basis upon which decisions to install one system or the other must be made is that of comparative total cost (investment and operating) of complete stations equipped one with each system, a definite minimum of operating reliability being set in each case. It is seldom that this problem is solved by the direct substitution of one system for the other, leaving the remainder of the station unchanged. Usually the change involves other elements of the steam cycle as well. For instance, with auxiliary exhaust feed heating, economizers of a certain size may be most economical; while, if multi-stage bleeding is considered, the economical boiler feed temperature may be raised so close to the boiler water temperature that the economizers either may not pay at all or should be much smaller.

Differences of opinion existing on this question are differences as to the comparative cost and reliability of practical schemes for realizing the best from each of the systems, and not as to the thermal efficiencies of the systems.

B. C. Sprague,
West Penn Power Co., Springdale, Pa.

When deciding between the use of stage bleeding with motor driven auxiliaries or the use of turbine driven auxiliaries, consideration must be given to the following factors:

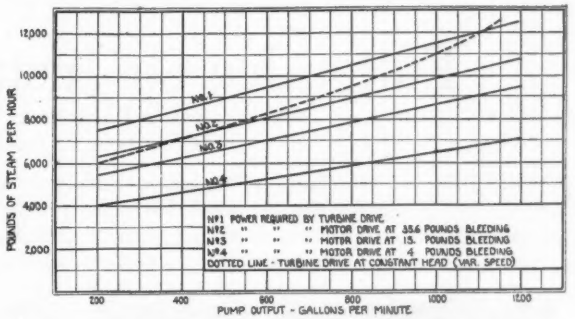
(1) The relative steam consumption of the two methods of auxiliary drive.

(2) The relative cost of installation and maintenance.

(3) The relative operating security as regards continuity of operation.

Feed water heating can be done much more economically by the use of steam bled from a main turbine than by the use of exhaust steam from auxiliaries' turbines. This greater economy with extracted steam is largely due to the greater efficiency of the main turbine which will extract approximately twice as much energy from the steam used for feed water heating as will even the larger auxiliary drive turbines when expanding to the same back pressure. After allowing for the transformer and motor losses there is still a large net saving in favor of the motor drive and bleeder heating.

Where turbines have been used for auxiliary drive it has been the practice to exhaust them into a common exhaust header at a pressure somewhere near that of the atmosphere. The part of the steam used for initial heating of the condensate water could have been expanded to a much lower absolute pressure before being taken from the turbine for feed water heating if the auxiliary drive turbines were arranged to exhaust at different pressures into different exhaust headers. The large amount of extra piping and equipment that would be necessary would render this arrangement impractical for use with auxiliary drive turbines, but with main turbine extraction heating it has been found practical to extract steam at two or more different pressures, thus taking advantage as far as practically possible of the increased amount of energy made available by expanding to lower pressures. Due to these possibilities



COMPARISON OF POWER REQUIRED FOR DRIVING CENTRIFUGAL BOILER FEED PUMP WITH AUXILIARY TURBINES AND WITH CONSTANT SPEED MOTORS

of effecting a more complete expansion of the steam used for feed water heating, the saving in steam consumption by the use of bleeder heating will be even greater than that due to the difference in the rankine cycle efficiency ratios of the main and auxiliary turbines.

It is probably more important to secure continuity of operation of boiler feed pumps than that of any other auxiliaries. Partly for this reason they are usually the last auxiliary to be changed from steam to motor drive. The accompanying diagram shows a comparison of the steam consumption of a turbine driven pump and one with motor drive. In the case of the motor drive the steam consumption shown is that required to be added at the main turbine throttle to generate the increased amount of power required by the boiler feed pump motor, and to permit of bleeding steam to accomplish an amount of feed water heating, equivalent to that done by the steam that would be exhausted by a boiler feed pump, without decreasing the amount of electrical output from the station. The steam consumption of a turbine driven boiler feed pump when supplying a given amount of water, is less when pumping less than the maximum output, if the reduced output is secured by reducing the pump speed rather than by throttling the feed water pump discharge at the pump or at the boiler drum. For this reason two steam consumption curves are shown for

the boiler feed pump, No. 1 is with constant speed and No. 2 is with constant discharge pressure at the boiler feed pump, obtained by varying the pump speed. Three curves are shown for the steam requirements for the motor driven boiler feed pumps. The steam requirements are shown to be smaller when it is possible to accomplish the equivalent amount of feed water heating with steam exhausted at 4 lb. absolute pressure. In many plants the possibilities of heating the feed water with steam extracted at this low pressure would already have been taken advantage of and it would be necessary to extract steam at a pressure somewhat near that of the atmosphere to do the heating that would have been done by a boiler feed pump turbine exhausting at atmospheric pressure. In this case the steam required with the motor drive is shown in curve No. 3.

The relative investment required for the two drives depends upon the amount of additional equipment used to secure continuity of operation with the electric drive. Reliability may be secured in a number of ways;

(1) By the use of a small house generator capable of carrying the most important auxiliaries in case of trouble.

(2) By the use of dual drive for the most important auxiliaries.

(3) By the use of an emergency generator which normally floats on the line and picks up the auxiliary load in case of a drop in frequency.

(4) By the use of shaft driven generators.

House generators have been used in a number of stations built during the last few years. The rankine cycle efficiency ratio of these turbo-generators is approximately 80 per cent as high as that of the main unit. Because of this lower efficiency and also because the house generator does not lend itself well to multi-stage bleeding, it has been considered desirable to secure all of the heating steam by bleeding the main units turbines.

The present tendency is toward the use of emergency or shaft driven generators for securing continuity of operation of auxiliaries, thus permitting the extraction of all heater steam from the main turbines. One possible solution lies in the use of the shaft driven direct current generators on each main turbine shaft of sufficient size to furnish current for excitation and for the operation of the condenser auxiliaries. It seems probable that some simple method for securing reliable auxiliary operation will be worked out that will not require an investment much larger than that required for auxiliary drive turbines and will permit the bleeding of all steam for feed water heating from the main turbines.

Fulton Ice Co. Installs Electrified Plant

Motor Drive and Water Treatment are Features of Chicago Raw Water Ice Plant

ONE of the new ice plants in Chicago which is typical of the electrically-driven raw-water plants, which have come into such general use, is that of the Fulton Ice Co. at 74th and South Ada streets. Figure 1 shows a general

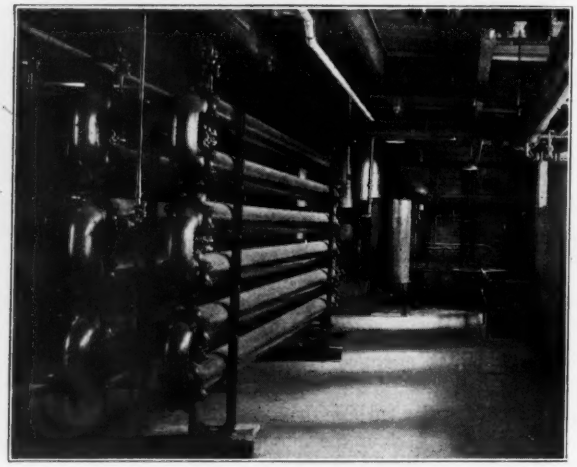


FIG. 1. RAW WATER BOX, CHEMICAL CONTROL TANKS AND A PORTION OF AMMONIA CONDENSERS

view of the machine and ice tank room, which is large enough for the addition of a second ice tank and direct connected ammonia compressor. These, when installed, will double the capacity of the present plant. The machine room now contains two ammonia compressors, one 11 by 22-in. Frick duplex, horizontal, double-acting compressor direct connected to a 165-hp., 100 r.p.m., Electric Machinery Manufacturing Co.'s synchronous motor equipped with an automatic, full-voltage type starter operated with push button, and one 12 by 12-in. Frick vertical, two-cylinder, single-acting, enclosed crankcase compressor driven by a belt with a Lenix idler, from a 100-hp. 865 r.p.m. Allis-Chalmers slip ring motor. This motor is equipped with two pulleys, which will run the compressor either at 83 or 166 r.p.m., giving sufficient flexibility to meet any demand during the various seasons.

There are two 17½-kw. motor-generator exciter sets, one being a spare unit, each of which will furnish sufficient excitations for both direct connected compressors after the second is installed. The rotary direct-connected air compressor, dehydrates with brine pump, ammonia receiver and ammonia regenerator are also located in this room, together with the switchboard from which all the electrical apparatus is controlled.

The ice tank is designed for can baskets, and contains 1024-400-lb. cans, arranged 32 cans wide by 32 cans long. Eight cans are handled by the crane at one time, the cans being held together in a steel basket which is operated as one unit. A 3-hp. electric traveling crane handles the ice with extreme ease and a minimum of labor. The tank is equipped with two-shell type brine coolers located at opposite ends of the tank, and agitation is derived from four horizontal brine agitators operated by vertical motors. The air system is of the Dimco medium pressure drop pipe type.

An ice storage room 100 ft. by 69 ft. by 16½ ft. high, serves both as a daily and a season ice storage. It has a capacity of approximately 2400 T. when the ice is stored eight tiers high, as accomplished by means of a Gifford Wood motor-driven tiering machine.

There is a second floor over the machine room only, in which are located six stands, each six pipes high, of Vogt multi-tube ammonia condensers, together with the water circulating pumps, ammonia oil trap, ammonia discharge gas hot water heater, surge tank for the spray

cooling system, cold water storage tank for softened water, and Graver chemical mixing apparatus for softening purposes. The condenser water is cooled by means of a spray system having a capacity of 800 g.p.m., located on the roof of the ice storage.

All pipe connections throughout are designed to permit doubling the capacity of the plant by merely adding

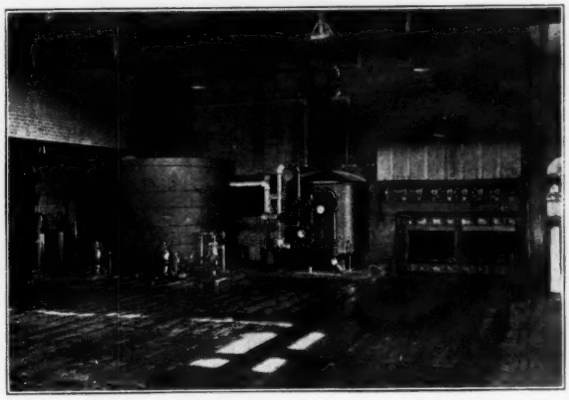


FIG. 2. CAN FLOOR WITH SETTLING TANKS AND FILTERS OF SOFTENER IN BACKGROUND

additional units without rearranging or increasing in size any piping.

In connection with the water softening system there is a wooden settling tank is 10 ft. in diameter by 16 ft. high, located at one end of the ice tank and extending from the concrete floor under the ice tank to a point just under the crane rails. This leaves space for the can dump opposite the settling tank, which is easily accessible as the

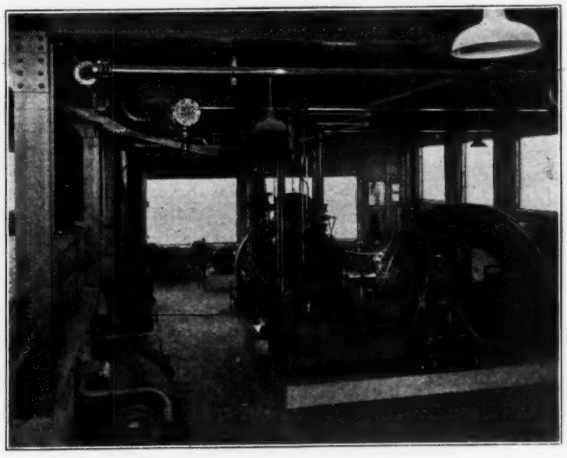


FIG. 3. COMPRESSOR ROOM WITH CAN FLOOR AT THE LEFT

crane passes over the top of the settling tank. At the time the second ice tank is installed a second storage tank will be similarly placed, giving the necessary four-hour reaction time for the water required for a plant twice the present size.

The present settling tank is complete with a 30-in. circular wooden downtake, which receives the discharge from the water proportioning tank on the second floor, shown in Fig. 2. This proportioning tank, supported on cast-iron stands, is 31 in. in diameter by 5 ft. 8 in. high, having a cone bottom. It operates on the submerged orifice principle, dividing the water in two portions in direct ratio to the flow required in the ice plant. A small portion passes to a 3-ft. by 2-ft. 6-in. control tank. A float in this tank lowers a circular swing pipe in the chemical tank. The chemical is thus measured by displacement. This chemical mixes with the major part of water discharged through the large submerged orifice in the conical bottom of the hard water proportioner and passes by gravity into the downtake of the settling tank. The proportioner is rated at 3500 gal. per hr., but it operates as efficiently now at 50 per cent capacity as it ultimately will under full load.

After settling, the water is taken by a small direct connected centrifugal pump shown at the rear of the filter in Fig. 3, and is pumped through a 6-ft. diameter Graver quartz filter to the storage tank on the second floor, from which it flows by gravity to the can-filling tank, which automatically regulates the correct quantity of water for each can. An alum put and venturi tube proportioner is a part of the filter.

Water which is used shows the following analysis:

	Grains per gallon
Calcium carbonate	4.90
Magnesium carbonate	1.09
Magnesium sulphate	1.90
Silica	0.18
Iron and aluminum oxides	0.15
Sodium sulphate	0.57
Sodium chloride	1.23
Total solids	10.02

With correct treatment of this water no cores are pulled, and the ice is crystal clear throughout, without blemishes of any kind. The average power consumption during the month of July was 42 kw.-hr. per ton of ice produced.

This plant was built by George B. Bright Co., refrigerating engineers and architects of Detroit, Mich.

SUGGESTIONS FOR handling and storage of coal:

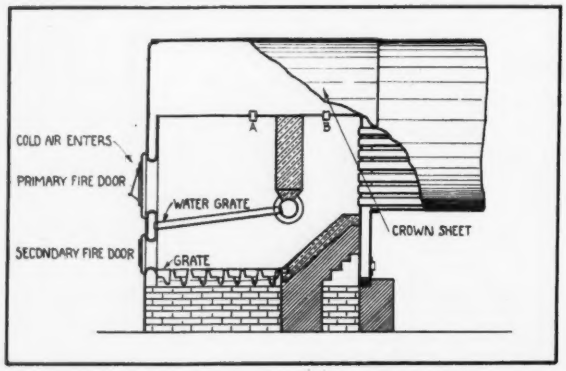
a. Do not handle coal in the open in the heat of the day.
b. Do not pile higher than 12 ft. No part of the interior of the pile should be more than 10 ft. from an air cooled surface.
c. Store only screened nut coal.
d. Eliminate all dust possible. Minimize handling.
e. Arrange pile so that the fine and coarse are evenly distributed, thereby eliminating air passages.
f. Re-handle and screen after two months.
g. Keep stored coal away from all sources of heat.
h. Allow six weeks seasoning after mining and before storing.
i. Avoid intermittent wetting and drying.
j. Avoid air transmission to the piles through and around foreign objects.

GRATES HAVE the primary purpose of supporting the fuel bed. At the same time it is necessary that they admit sufficient air for combustion and void ash freely at all points. The width of air space is determined by the coal to be burned. It should be as wide as possible and still not allow coal to drop through. Air space distribution should be such that the grate will be left uniformly cool.

LETTERS DIRECT FROM THE PLANT

Fusible Plugs

IN THE letter published in the Dec. 15 issue, from Walter H. Fittus, the question was raised as to the value of fusible plugs placed at position "A" in down-draft heating boilers. Perhaps an explanation of the reason for placing the fusible plug in this position would be interesting.



TYPICAL DOWN-DRAFT HEATING FURNACE SHOWING USUAL LOCATION OF FUSIBLE PLUG AT "A"

When the fusible plug is placed in position "B," it becomes inaccessible unless the brick wall resting on top of the water-grate header is removed. When a fusible plug is placed in an almost inaccessible position of this kind, it is usual for the ordinary operator when replacing this plug to use an ordinary cast-iron plug so that he may not be bothered by future burning out of the plug. This does not give the protection desired against low water. When the plug is placed in position "A," it is accessible at all times and the only question would be whether or not it will melt at the same time as one placed in position "B." Repeated tests of a boiler with plugs placed at both "A" and "B" show that the plug at "A" is more sensitive than the one placed at "B." I believe that this can be attributed to the radiant heat from the fire on the water grate.

Attention is directed to the proposed revision of the A. S. M. E. boiler code as published on page 716 of the December issue of Mechanical Engineering. Paragraph 430-V as revised reads as follows:

Par. 430: Every boiler may have one or more fusible plugs, located at the lowest permissible water level as follows:

v. For other types and new designs, fusible plugs shall be placed at the lowest permissible water level, subject to direct radiant heat of the fire or in the direct path of the products of combustion, as near the primary combustion chamber as possible.

The change from the present code is the addition of the words "subject to the direct radiant heat of the fire." Radiant heat is admittedly more active and of more value than convective heat, and I believe that a boiler is just as safe with a fusible plug placed in position "A" as when placed in position "B."

In proof of this point, there are more than 50,000 boilers of this type in service today with no crown sheet failures reported.

Kewanee, Ill. C. E. BRONSON.

Dragline Conveyor Handles Material Under Water

USE OF a dragline cableway excavator has proved the best method for widening and deepening the hydraulic canal at Cohoes, N. Y. As it was necessary to keep the hydroelectric plant in operation equipment had to be used that could handle material under water. A dragline excavator was installed, having a 400-ft. span. During the first month of operation the cableway excavated over 7000 cu. yd. of earth, all under water. During the second month the plant handled 4650 cu. yd. of earth and 2630 cu. yd. of rock. The rock was shale, which required but little blasting. The accompanying photograph shows how the cableway spanned the channel and delivered the material to a hopper. Water from the canal was pumped into the hopper and the spoil was sluiced to the river bank near the power house. As the tower at the tail end of the cableway was movable, a large fan-shaped area could be excavated at a single set-up.

DRAGLINE CONVEYOR IS USED FOR DREDGING HYDRAULIC POWER HOUSE CANAL

Chicago, Ill. GEO. F. PAUL.

Soldered vs. Leaded Joints

ON PAGE 1153 of the Nov. 15 issue of Power Plant Engineering, C. Rye offers some suggestions in regard to soldering. As this is work with which I have had considerable experience, I was interested. I fail to under-

stand, however, what his reasons were for carrying a pot of hot lead up five flights of stairs to do a soldering job. If melted lead is poured upon the ends of metal pipes or heavy twisted metal wires the lead will cool enough to harden almost instantly and it cannot be removed by pouring more hot lead upon the joint unless the lead is almost red hot; with solder it is a different proposition.

Clean surfaced solder can be removed from pipes or wires, and the pipe or wires wiped clean with a rag. Solder has a much lower temperature than what would be required to do the work with lead.

In reference to applying mercury to a joint to dissolve the lead in the solder, my opinion is that the advice is not good. I believe Mr. Rye is mistaken in making the statement that mercury does not affect anything but the solder of the joint. In a comparatively short time mercury covering copper, brass, German silver, nickel and some other metals will penetrate them and destroy their ability to stand repeated bending without cracking; the color of brass and copper will be changed to a dull white. If I am not mistaken, iron and platinum are the only metals not affected by being immersed in mercury for a long or short period.

Toronto, Ont. JAMES NOBLE.

Recording Thermometer on Reboiler

WE HAVE HAD trouble with the steam trap on our reboiler coils and at times made bad ice, due to the trap stopping and letting the water cool off. The reboiler is located on the roof, and the engineer was supposed to go up there every hour, but it is easy for a man to forget or get careless when the trouble is likely to be infrequent.

In order that we might better keep track of the reboiler temperature, we ordered a recording thermometer with 30 ft. of tube and placed the instrument so that it is under the eye of the fireman at all times and the engineer cannot miss it when going into the fire room. When everything is operating properly, it draws a true line at 212 deg.; but if the trap stops, the temperature starts down and someone will see it in a few minutes and get busy.

These charts make a permanent record which may be valuable if other troubles occur, causing the white ice, due to air, as it will eliminate the reboiler as the cause. L. D. C.

Trolley Wire as Concrete Reinforcement

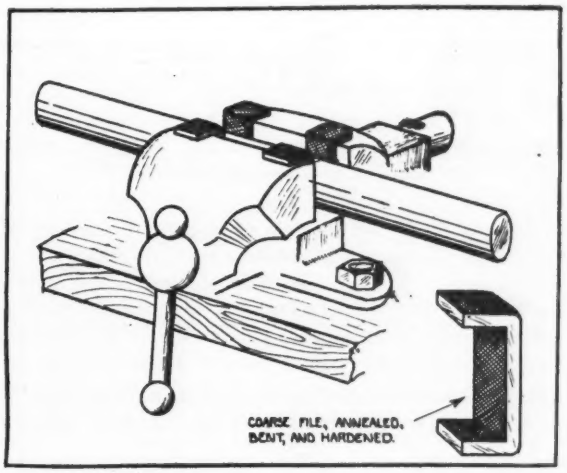
LAST SPRING it was desired to install a number of reactors in a large power station. As the room in the portion of the building where these reactors were to be placed was limited, it was necessary to place them on closer centers than is ordinarily the case. Calculation showed that if the floor were not reinforced it would not be strong enough to carry the weight safely. It was known that if iron were used as the reinforcing material, the stray currents set up in it would heat the iron to such an extent that it would be seriously weakened. In fact, where one of the reactors had been placed on unreinforced concrete but near to an iron beam in the floor, it was found that the beam became heated when the reactor was in service.

It was decided then to use twisted bronze rods of square cross-section, but it was found that it would take considerable time to obtain such rods and it was desired to finish the work in the shortest possible time. The power station supplied power to a trolley system and the electrical engineer suggested that lengths of the trolley wire be cut up and bent to the desired shapes and installed in place of the bronze rods. One of the sizes of trolley wire used by the railway company had approximately the same strength as the rods which it had been proposed to use and there was sufficient of it on hand to permit of its being used as reinforcement. The wire was cut up, bent, and installed, and there has been no trouble in regard to its heating, the only precaution that it was necessary to take being that the ends of the wires did not touch each other and form closed circuits. When that happened, there was trouble from heating.

Westfield, N. J. G. H. MCKELWAY.

File Clips for Vise Jaws

BENT FILE clips such as illustrated in the accompanying sketch are the means which were devised and are used by a mechanic in a stock room of a machine shop, for use in gripping cold rolled steel, brass rod and



SIMPLE FILE CLIPS FOR USE BETWEEN VISE JAWS FOR HOLDING SMOOTH STOCK

smooth brass pipe in the vise, while cutting to lengths with a circular cutter. These parts are equally valuable in holding any part between the vise jaws where it is desired to prevent it from moving while working.

These grips are simple fixtures to make up. They are parts of old coarse files, which are annealed first to cut into sections with a cold chisel, then heated and the edges turned at right angles. After bending, they are hardened and are ready for use.

On the many jobs where parts persistently slip in the vise jaws, these small grips are readily attached, providing a firm hold on the work while chipping, sawing, filing or assembling parts.

Washington, D. C. G. A. LUERS.

Drop in Steam Line

In the Dec. 15 issue, L. F. W. submits a pair of diagrams, showing a sloping steam line, and wishes to know whether a restricted steam lead is the cause. It may be and then again it may not be, probably the latter. The right-hand diagram shows a little later steam lead than the other, this lead may be increased. If these diagrams were taken from a three-way cock, it is advisable to have the corners slightly rounded.

There are a few things L. F. W. has not mentioned. Has the engine single or double ported valves? If the former, it may be possible the flow of steam through into the cylinder is not sufficient to keep up the line. Again, has the engine been speeded up beyond the speed it originally had? If so, this would tend to produce the wire drawing effect, as the increased piston displacement would increase the steam velocity through the ports.

FIG. 1

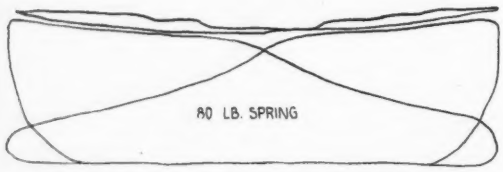


FIG. 2

FIG. 1. DIAGRAM TAKEN FROM STEAM THROTTLE VALVE
FIG. 2. DIAGRAM SHOWING ACTION OF STEAM IN ENGINE CYLINDER

If it is possible the engineer could attach the indicator to an opening in the steam pipe, just above the throttle valve, and take a diagram. Then, attach the indicator to the throttle valve, close to where it is bolted on to the cylinder, take a diagram and compare it with the former, measuring from the atmospheric line in both cases.

The writer once ran up against a proposition similar to this: Diagram Fig. 1 was taken from the throttle valve. A second diagram, Fig. 2, was taken; the diagram from the steam (throttle) valve and atmospheric line being drawn, paper quickly removed, and placed on the drum of a second indicator, so the pencil would draw an atmosphere line coinciding with the one already drawn, and diagram taken showing action of steam in cylinder. It will be noticed the drop in steam lines in both diagrams follow each other closely. Judging from these diagrams, the conclusion was reached that the wire drawing was due mostly to the throttle valve. This may be the condition of L. F. W.'s engine. Again, it possibly may be that the area of valve ports in the cylinder is too small—possible, but hardly probable, as the ports are designed with ample areas if the castings are right with the drawings.

Tom Jones.

On page 1252, Dec. 15 issue, L. F. W. shows a diagram from a Reynolds Corliss engine, 16 by 36 in. at 120-lb. steam pressure, for 108 kv.a. load on a 200 kv.a. alternator.

The diagram is a little better balanced on the crank end than on the head end as to the steam line.

The writer believes that the area taken up by the piston rod has some effect in giving some less slant on the steam line at the point of admission.

The head end slanting line from the point of admission might be caused by a worn cylinder and worn piston rings, but the "no load" card and also the "full load" should be taken in order to be certain.

The compression line and admission line are nearly perfect. Expansion and release are practically perfect.

I would consider this a good practical card considering the load at the time the card was taken; as there is no such thing as the ideal diagram. Valves cannot open quickly enough, thus causing rounding corners. Also the ports offer some resistance to the passage of steam, causing the horizontal lines to droop.

If, however, the slant corresponds proportionally from the point of admission on a 200-kv.a. load, it would indicate by this slant an insufficient steam supply, which might be due to the choking or wire drawing of the steam from having ports too small. I would suggest also that a steam gage be placed on the 8-in. header and another on the 5-in. header about 16 in. above the steam chest, to record the drop in steam pressure from the boiler header to the steam chest.

Rockford, Ill. C. M. Westcott.

Cooling Turbine with Live Steam

On page 1154 of your Nov. 15 issue, Mr. Morris requests information regarding the heating of a turbine when running idle. As nobody has as yet answered this query, I am advancing the following theory, which is deduced from the question. The generator is brought up to speed by the turbine and after the synchronization of the generator the throttle is closed. Assuming no more steam to be admitted to the turbine, as was probably the case before,

the 1½-in. line was cut in, then the turbine would have an action somewhat similar to a multi-vane air blower. This would tend to produce a vacuum in the turbine, which means that there would be in the turbine the same condition as obtains in a rotary pump when it is working against a closed valve, i. e., churning.

Here we have, I believe, the cause of the heating, friction of a fluid between two solids. According to Kent, the friction of a fluid, whether liquid or gaseous, is proportional to the area of rubbing surface and the square of the velocity at moderate and high speeds. The area of rubbing surface would be largest in the low pressure stage of the turbine and the peripheral speed would be greatest, which would account for the low pressure end heating up much more quickly than the high pressure end. Although the heating effect might be small, it would be cumulative and would affect equally rotor, stator and fluid medium. In the high pressure stage the steam bled through for cooling would undoubtedly give up some of its heat energy, and by the time it reached the low pressure stage would have expanded until in all probability it would be below atmospheric pressure. At such pressure it would be comparatively cool and would absorb heat from anything at a higher temperature than itself. It would seem that the admission of air into the turbine might also serve to keep it cool provided the air was quantitatively sufficient. This is mere speculation, but even so, I think it is worthy of a tryout. Certainly the steam used is worth saving, if possible. As to the fact of less steam being used at night, the difference in temperature would make quite a difference in the diffusion of heat by radiation, with a given size of the unit and temperature difference, a fairly close calculation of the heat diffusion could be made. This could be compared with the amount of steam saved during the cooler part of the day. A test of this nature, made during the hotter part of the day and again during the cooler part, would give a good idea as to how far diffusion was responsible for the saving of steam. Also it might be used as a basis for calculating the amount of heat generated by the turbine.

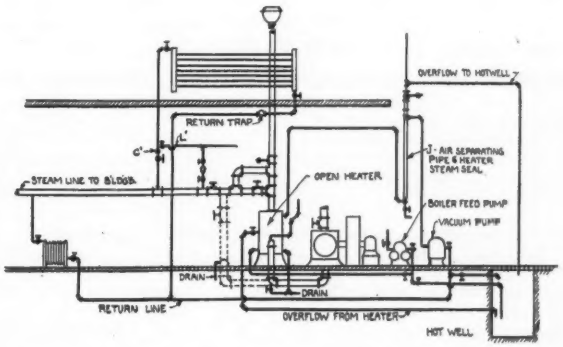
No. Battleford, Sask., Canada. REG. A. WOODS.

Utilization of Exhaust Steam

IN REPLY to E. W. M.'s question on page 1105 of the Nov. 1 issue of Power Plant Engineering I would say that the cause of some parts of the system not heating is partially indicated in his paragraph where he says he gets sufficient return steam to heat the feed water without using the exhaust steam from the engine. This indicates that steam is blowing right through some of the return lines from the different parts to the return main. This steam binds the vacuum pump on one end of the line and backs the return water into the office radiators. The dry room radiator using live steam at a higher pressure is blowing steam right through the return trap to the return main. This condition holds the water in radiator in the office on account of the lower steam pressure. No steam should be allowed to blow through the trap to the vacuum return main except that which escapes when the trap discharges. Radiator return valves on the end of each live steam radiator would, if properly adjusted, drain the coils with less steam escaping and by keeping a vacuum in the return main and the branches up to the radiator traps the condensate would not accumulate in the return lines.

Utilization of 10 lb. back pressure on the engine is excessive and expensive. If the piping of the system is large enough to carry the volume of steam required with sufficient radiator surface in each room, from ½ lb. to 2 lb. gage back pressure should be sufficient to heat the rooms to 78 or 85 deg. with the exhaust from the 150-hp. engine which if working up to full load should be able to supply a heating system of 26,000 to 30,000 sq. ft. of radiation surface. If more steam is needed, it could be supplied through a reducing valve from the high-pressure steam header.

To have the condensate return properly from the end of the 250-ft. line would require from 18 to 20 in. of vacuum and even then the steam must not enter in the return main in such volume as to destroy the vacuum or to overtax the capacity of the vacuum pump. It is not necessary to place the vacuum pump at the lowest point of the system, but all air and water pockets in the pipe lines should be eliminated. Where a closed heater is used on a vacuum heating system, a comparatively high vacuum can be carried on the engine but with open heaters there must be some back pressure in the heater at all times



VACUUM HEATING SYSTEM FOR BOTH LIVE AND EXHAUST STEAM

Keep the radiator return traps in good order at all times and there will be less trouble from short circuits. The vacuum pump can be set on the engine room floor for even higher lift than 3 ft., but it must have a fairly air-tight return main to draw the water from the office 250 ft. away.

Cambridge, Mass. R. A. CULTRA.

Ammonia Suction Line Can Be Covered While in Service

SOME TIME BACK, an inquiry was made about covering a suction pipe while it was in operation and it was stated that an auxiliary suction line ought to be erected for use while the other was defrosted and then covered. We run across jobs like this quite frequently and our method is to chip off as much of the ice as possible, then take a pail of brine from the brine tank and apply it with a sponge or piece of waste to the pipe. This brine, being in regular operation, is strong enough to withstand freezing and will melt off the remainder of the ice and the pipe will drain dry so that a tight job of covering can be made. A laborer helping the pipe coverer can keep the pipe ahead of him in condition to work on.

Nassau, Bahamas. JOHN H. RYAN.

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Economic Gain Results from Coal Storage

By those who have advocated the storage of coal as a means of relieving the railway transportation situation during the later months of the year and also as a means of reducing prices and stabilizing production, the conditions throughout the year 1923 will be viewed with a great deal of satisfaction.

In former years, as far back as records are available, the amount of coal in storage has fluctuated greatly with apparently no season of the year which could be recognized by a peak. Threatened strikes of miners have usually sent the stocks up and the prices have risen in harmony with the demand for storage coal. In 1923, no strike of importance occurred in the bituminous coal mining industry to upset production conditions. This, combined with the general campaign to store coal during the summer months, has resulted in a remarkably steady output of coal throughout the entire year, a gradual increase in stocks of coal in storage from May to October and a decline of about 50 per cent in the spot price of coal f. o. b. mines from January to October. One of the most important results is the beneficial effect this storage practice has had upon railway transportation. At no time during the year has a car shortage occurred, which is decidedly unusual during that season when agricultural crops are being marketed. The railroads themselves have done much to bring about this desirable result by completing their storage requirements by October 1 when they held in storage 16,600,000 T. of coal. They also established a new record in the amount of coal moved to Lake Erie ports for shipment by water up the lakes.

As to the power plant industry, it is encouraging to note that the electric utilities held in storage over 6,000,000 T. on September 1, which is 20 per cent more than they stored prior to the strike in 1918 and represents a substantial growth of the coal storage practice.

It may cost $0.50 to $1.00 a ton to store coal for use in power plants but, if the f. o. b. mines price is reduced over $2.00 a ton, as occurred between January and August of last year, by storing coal consistently a distinct economic gain will result just as advocates of the practice have stated.

Supplying Torrents of Steam

Consider the flood of steam that must be fed to a modern generating unit. For a 40,000 kw. turbine at 8 lb. of steam per kw.-hr., 320,000 lb. of steam an hour must be supplied. A stream which flows at 4 mi. per hr. has the characteristics of a mountain torrent but we send steam rushing through piping at a mile a minute and in quantity to tear away a mountain side. Whence shall we get these huge streams of steam?

Boilers working at 2500 to 3000 hp. each are becoming frequent, but it takes four of them to supply one 40,000 kw. turbine and consideration is being given to 60,000 and 75,000 kw. turbines for future super stations. One boiler of 3000 hp. calls for a grate surface of some 900 sq. ft. even at the forced rate of burning used in these big units,—an area 30 by 30 ft. So the problem becomes—Where shall we put the grates? And what is to be done with the bigger boilers which are likely to come in the future?

Some form of fuel which can be burned without grates is one solution. Gas is barred by expense; oil by limita-

tion of supply; powdered coal or coke is being pushed and is giving a good account of itself. It is fortunate that records from plants using pulverized fuel show high efficiencies, for it may probably be that, to supply the great streams of steam demanded by future units, powdered coal will be found essential because of the high combustion rate which will be imperative, if units are to be kept within reasonable dimensions.

Complications in Use of High-Pressure Steam

Distinct progress is being made in the use of steam at pressures from 500 to 1200 lb., but the problems involved are quite different from those met in going from 100 to 500 lb. Designers of equipment do not have complete, authentic, experimental data relative to the behavior of steam at pressures above 650 lb. and will be considerably handicapped until the experimental work on the steam tables now being conducted by the U. S. Bureau of Standards is completed.

Much higher pressures than are likely to be used with steam have been successfully handled in hydraulic press work so no particular difficulty will be encountered in designing for pressure. Accompanying an increase in steam pressure, however, is an increase in temperature which apparently is the limiting factor in modern design, due to the fact that metals now used in boilers, piping and turbines lose decidedly in tensile strength when the temperature reaches the neighborhood of 750 deg. F.

Another factor of great importance in the design of turbines is the accumulation of moisture in the lower stages, but as the pressures increase, the amount that the steam can be superheated becomes less, due to the limiting temperature. Two methods of preventing this moisture accumulation have been suggested; the first is to tap the turbine cylinder at several points and drain the water off as it collects; the second is to reheat the steam after it has passed through the upper stages of the turbine and thus keep its temperature above the saturation point throughout the entire turbine.

Another practice resorted to is bleeding the turbine ahead of the last stages, using the steam for heating feed water. This not only keeps down the size of the turbine but saves heat units that would otherwise go to waste through the condenser.

These complications are the inevitable price that must be paid for higher efficiency and to what extent they will be justified can be determined only after the pioneering work has been done and equipment is built on a commercial basis.

Off Duty

A story is told of Michael Faraday, who when he had demonstrated the principle of electro-magnetic induction by moving a wire before an electro-magnet was asked of what use he expected the phenomenon to be. "Of what use?" repeated the great scientist thoughtfully. "Of what use is a new born baby?"

Anybody who today visits one of our large power stations where 50,000-kw. generators are whirring out the electrical life blood of our communities and industries will fully appreciate the significance of Faraday's remark. It is a far reach from Faraday's electromagnetic toy to the ponderous electric generators of today, but the chain which links them together is complete—there are no missing links. The same principles which governed the action of Faraday's crude apparatus govern the action of the large generators of today.

Faraday's reply is the same that might be given in answer to similar questions asked today. Go to any of the great scientific laboratories of the world and observe the nature of the research the men are engaged in.

Some time ago, could you have visited the research laboratories of the General Electric Co., you would have found them studying the action of a peculiar little glass bulb into which two electrodes were sealed. The inside walls of this bulb were coated with silver with the exception of a small area through which light could be admitted. When a beam of light was focused through the clear spot and a voltage applied to the two electrodes, an electric current passed between them. The stronger the light the greater the current.

Now, to an electrophysicist this was no doubt an interesting experiment, but the skeptical observer might have ventured the question, "Of what use is it?"

In this case the answer would have been different from the one Faraday gave, for there was a use for this little glass cell even before it was discovered. For many years, the electrophysicist had been searching for a device which would instantly alter the flow of electric current when subjected to the action of light. And when it was finally perfected, it was put to work at once.

You have, no doubt, heard of the Pallophotophone, that wonderful device which photographs the human voice on a strip of sensitized film, and which, when the film is run through the machine again, reproduces the voice in all its infinite shades of tone. That was one application of this little photoelectric cell.

Another application has been made to the sorting of cigars by color. In this process the cigars are carried on a mechanical conveyor and at a certain point a beam of light strikes the cigar. The light reflected from the cigar falls on the eye of the photoelectric cell and since the cell current changes as the light intensity varies, the current from the cell, through an amplifier causes mechanical gates to operate through which the cigars fall into boxes graded according to color. By means of this device, it is possible to sort cigars much faster and more accurately than by hand or by any other sort of method heretofore devised. Extremely practical and very useful isn't it?

And yet, the whole working of this device is dependent upon the principles governing the flow of electricity through gases. These principles, by the way, were not discovered in a cigar factory.

Of what use is it? What mortal has the right to ask that question unless he is sincere or does so with the intention of answering it? Who is he, that takes it upon himself to decide which among nature's hidden treasures are to be discarded and which saved? In the ultimate analysis, all things are probably of use and it is up to us to do everything in our power to find those uses. Better let the skeptic ask, "Of what use am I?"

Yearly Index

INDEX for Volume XVII of Power Plant Engineering is now prepared and will be sent free to subscribers upon request.

Metropolitan Power Co. Is Installing 30,000 Kw.

SUSQUEHANNA PLANT TO HAVE AN ULTIMATE CAPACITY OF 200,000 KW. THE TWO FIRST UNITS WILL BE 30,000 KW. EACH AND WILL OPERATE UNDER 350 LB. PRESSURE

AT MIDDLETOWN, Pa., on the east bank of the Susquehanna River, approximately 12 mi. southeast of Harrisburg, Pa., will be one of a group of generating stations in the Pennsylvania-New Jersey Power System.

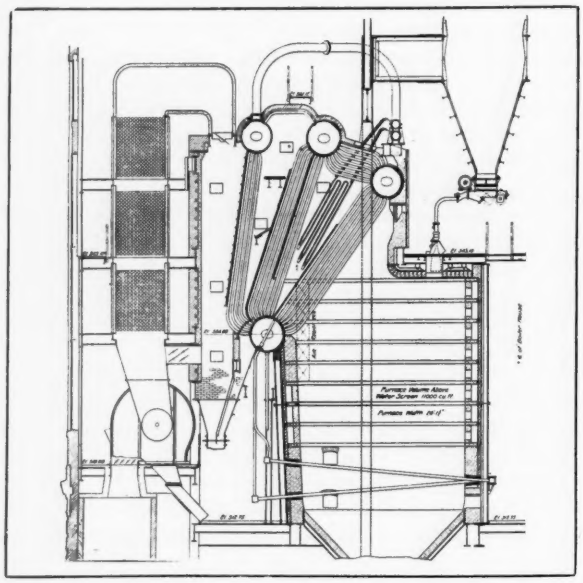


FIG. 1. EACH BOILER FURNACE WILL HAVE A NET VOLUME OF 11,000 CU. FT.

This system extends from New York and York Haven to within 30 mi. of New York City. It comprises the lines and stations of the Metropolitan Edison Co., Pennsylvania Edison Co., The New Jersey Power and Light Co., and their subsidiaries. The power plant site at Middletown is approximately 62 acres in extent. The station is designed for an ultimate capacity of 200,000 kw. consisting of six units the first two being of 30,000 kw. each. The first unit of 30,000 kw. capacity is in the course of construction at the present time. It is located at the up-stream end of the ultimate station, provision being made for extending the plant downstream parallel to the river. Each unit will have a screen house approximately 35 ft. in length by 34 ft. in width which will house traveling screens and trash racks.

Building construction is of steel frame, having reinforced concrete foundations with brick walls and limestone trimmings. It will probably cost less than the average modern power plant building of the same capacity, inasmuch as the flues are located in the basement and the chimneys in the rear of the building making a high building unnecessary. Concrete floors will be used except in the turbine room, which will have a tile floor.

Steam pressure to be carried by this plant will be 350 lb. per sq. in., and the superheat will be 220 deg. F. Five, 1477 hp. bent tube boilers, each having a heating surface of 14,770 sq. ft. with approximately 50 per cent of economizer surface will be installed. Each of the five boilers is equipped with a superheater having a heating surface of approximately 2150 sq. ft. capable of superheating the steam to 220 deg. F.

Cindervane induced draft fans located at the discharge of the economizers, will take out the ash remaining in the flue gas. These fans and the accompanying equipment are designed so that the boilers may be operated up to 350 per cent of rating, provision being made to bypass some of the flue gases around the economizers at higher ratings.

In the first unit the boilers are arranged three on one side and two, with place for a third, on the other side of a central aisle, which is located perpendicular to the river. Steel corrugated flues in the rear of the boilers and beneath the economizers and cindervane fans carry the flue gases to concrete chimneys 200 ft. high by 14 ft. inside top diameter. These corrugated steel flues function as air preheaters for the air needed for combustion, 65 per cent of which enters the furnaces in the rear of the setting.

In the coal preparation plant an overhead bunker, which is fed by a conveyer, will deliver the coal to six driers. Feeders under the driers will regulate the velocity of the coal through them. Two Fuller air separation type mills, two Raymond mills and one Hardinge conical ball mill will be provided. Each of the Fuller and Raymond mills are to be supplied by one drier while the Hardinge mill is to be supplied by two driers. There will be one Gayco separator provided for the Hardinge mill while the Fuller and Raymond mills are to be provided with exhausters and cyclone collectors. Cindervane fans will be provided at the flue gas discharge from the driers in order to reclaim any fine coal which might be pulled out of the driers. Two air transport pumps, one a spare, will be employed to deliver the pulverized coal to the boiler room where it will be placed in bunkers from which it is to be fed to the burners.

Boiler furnaces are being constructed with air cooled furnace walls. The furnaces are 24 ft. 1½ in. wide by 20 ft. deep inside and have a furnace volume above the water screen of 11,000 cu. ft. The furnace is enclosed

on all sides by means of a steel casing and is held rigid by means of I-beam buckstays. The wall consists of 4½ in. of insulation placed against the steel casing, then a 9-in. air space and then a 9-in. refractory wall. The refractory wall is tied to the steel casing by means of tile and cast iron clips.

About 65 per cent of the air needed for combustion is admitted to the air space in the rear and sides of the setting and is brought around through the side walls and enters the furnace through ports in the front.

In considering the matter of heating feed water it was decided to extract steam from the main turbine at various stages instead of using the exhaust from non-condensing steam turbine driven auxiliaries. In this way the temperature of the feed water is raised in steps to the desired final temperature. The saving which can be effected by this means is approximately 6.5 per cent on the coal pile. In view of this fact, all motor driven auxiliaries will be used with the exception of a dual driven exciter set and a dual driven circulating pump for maintaining the heat balance, while there is also a small turbine driven condensate pump, boiler feed pump, and house service pump to be used when starting up the station.

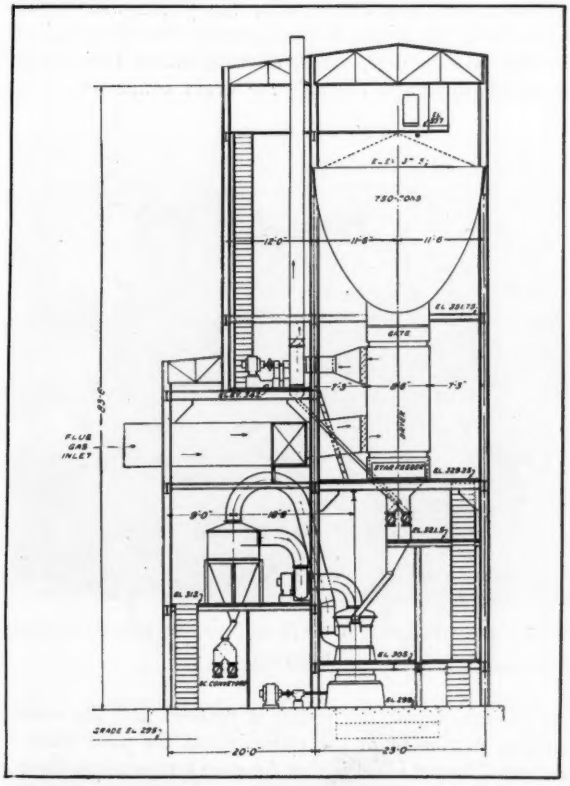


FIG. 2. ELEVATION OF THE PULVERIZED COAL PLANT

Steam for heating the feed water is extracted from the main turbine at the thirteenth and fifteenth stages. Condensate after leaving the hot well of the condenser goes through the inter and after condenser of the air ejectors on the condenser and jet heater, then to a closed heater to which steam is bled from the fifteenth stage of the turbine, then through a condenser which condenses high pressure packing steam from the turbine, then to a second closed heater to which steam is bled from the thirteenth stage of the turbine, and then to a jet or intimate contact heater which gets its steam from the dual driven exciter and circulating pump. The feed water temperature is controlled by means of a thermostatic control regulating the amount of steam from the dual drives.

In the operation of the station the control of all apparatus will be centralized as much as possible. In the boiler room an operating platform or gallery is located between the two rows of boilers at the same elevation as the pulverized coal burners and feeders. On this gallery will be located all of the boiler room instruments and meters, while the induced draft fans, the coal feeders to the burners and the air blast to the burners will all be regulated from here, so that ordinarily it will be possible for the operator to control everything in the boiler room without leaving this gallery. All of the auxiliary motors will also be controlled from one central point. There will be an indicating and repeating signal system installed.

Auxiliary transformers for the auxiliary motor drives will be located between the screen houses of the several units. In the first unit there will be one bank of 66,000 v. transformers and one bank of 110,000-v. transformers. There will be two 110,000-v. feeders and four 66,000-v. feeders. The generator leads will be carried in an underground tunnel which is designed to withstand water pressure to an outdoor substation located in the rear of the station beyond the coal storage.

New Plant for American Steel & Wire Co.

PLANS FOR the construction of an electric power plant costing approximately $5,000,000 are being prepared by the engineers of the American Steel & Wire Co. at Worcester, Mass.

At the present time, the company uses steam power. It is planned to have this replaced with electric power and individual motors for all machinery. In the three large units of the present plant, there are over a score of coal and oil-burning boilers. These small power plants will gradually be discontinued as the electrical equipment can be installed.

Work has already commenced, installing electric motors in some sections of the plants. For the present, current will be drawn from the New England Power Co.'s transmission lines by means of cables which will be laid under the old Blackstone river and along the old canal. The cables will be laid underground so as not to interfere with the overhead wires of the Worcester Electric Light Co.

It is planned to build the central power plant at the so-called South Works of the company and it will generate all the current required for the three units. Increasing demand for power with the growth of the three units, necessitating the addition of smaller power plants, has not only been bothersome, but has proven expensive in operation as compared to a central power plant.

It is expected that plans will soon be sufficiently far advanced to permit estimating on construction and equipment.

EXPORTS for 1923 have shown marked increase over 1922 for many industries. Among these are pipe and fittings, 30 per cent; internal-combustion engines, 26 per cent; electric motors and starters, 104 per cent; gas and fuel oil, 32 per cent; refined copper, 16 per cent.

Turbine Controlled by Temperature or Pressure

SINCE it is frequently desired to control a turbine at some distant point in response to variations in temperature or pressure, the Terry Steam Turbine Co., of Hartford, Conn., has developed a hydraulic relay device which will transmit the impulses from a thermostat or pressure diagram to a distance and at the same time magnify the

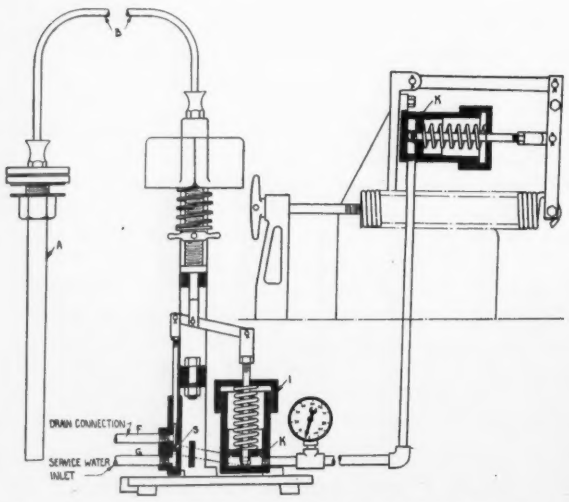


FIG. 1. ACTUATING MECHANISM OF THE HYDRAULIC RELAY FOR CONTROLLING TURBINE

power of these impulses so that they will control the turbine governor with positiveness.

In this relay, water at a pressure of 40 lb. or over from any clean source is employed as a motive fluid. The thermostat or pressure diaphragm has its stem so connected to the relay mechanism that the water pressure in a pipe leading to the turbine bears a direct relation to the position of the stem and hence to the temperature. The mechanism for accomplishing this is shown in Fig. 1.

The thermostat shown is of the volatile liquid type. "A" is the bulb for immersion in the water in the heater. It is connected by tube "B" to the diaphragm, which is opposed by a spring. The stem from the diaphragm is connected to the center of a "floating lever" one end of which is attached to a pilot valve and the other end to the piston rod of a pressure weighing cylinder.

Consider first the pilot valve. The head "S" of this valve normally covers the circular port (shown dotted) which connects with the space under the piston of the water cylinder. The service water inlet is below the valve head and the drain connection above the head. If temperature decreases, the thermostat stem will rise, lifting the pilot valve and admitting water under pressure through the port at "S." On the other hand, if the temperature increases, the thermostat stem will lower, allowing any water under pressure under the piston "K" to begin to escape through the drain connection "F."

Without the compensating effect of the water cylinder, even a slight change of temperature would put full water pressure on or off the line beyond the pilot valve. The water cylinder, in connection with the floating lever, however, gives a graduated effect in the following manner.

As shown in the diagram, the parts are in the position they would assume if the temperature of the feed water were at a maximum. The nut "I" is adjusted so that the spring on the piston is just tight without having any initial compression. There is no pressure on the water under the piston. Assume now that the temperature drops slightly. The pilot valve will lift, admitting water under pressure under the piston. This pressure will lift the piston, compressing the spring in direct proportion to the pressure of the water. This movement of the piston will tip the floating lever about its center pivot, moving the pilot valve towards a closed position. When the pilot valve is closed, no more water will enter, and a steady water pressure will be maintained under the piston. With a further drop in temperature the same movement will proceed and the pressure of the water under the piston will become higher still. On a rise in temperature, the movement of the stem will be downwards, allowing water from under the piston to escape through the drain connection until

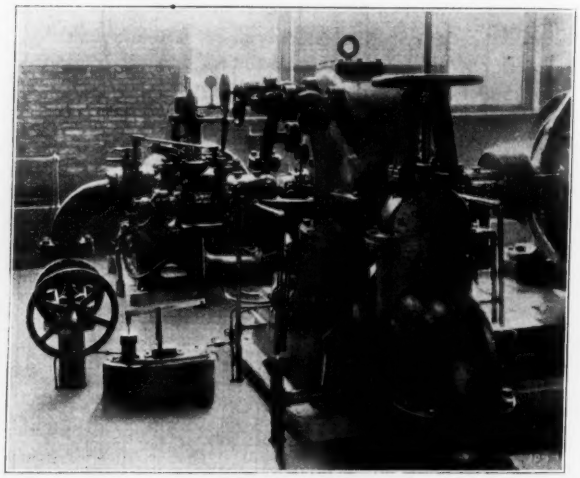


FIG. 2. DUPLEX EXCITER UNIT EQUIPPED WITH HYDRAULIC CONTROL

the pressure under the piston is reduced and the corresponding movement of the piston resets the pilot valve to neutral. The net effect is that for each temperature there is a definite water pressure under the piston, the pressure being greater with low temperatures and less with high temperatures.

As the water space under the piston of the water cylinder is in direct communication with the corresponding space under the piston which actuates the synchronizer spring, the tension in the synchronizer spring varies with the controlled water pressure. Therefore, if the feed water temperature is low, the synchronizer spring will be tight and the turbine will give more exhaust steam. The reverse takes place with higher temperature, the action being graduated at intermediate temperatures, and the effect being to hold the temperature steady.

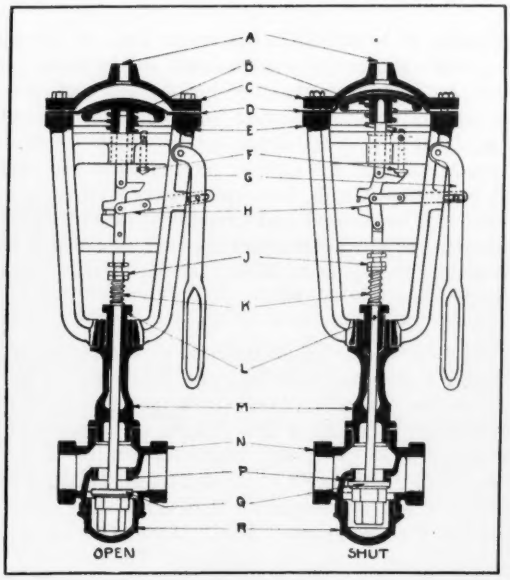
If the nut "I" is adjusted to give a little initial load on the spring, the first opening of the pilot valve will have to let in an appreciable pressure of water to cause the piston to begin to lift and reset the pilot valve. The result of this is to cause a definite and adjustable tension to be put on the synchronizer spring as a minimum. This does away with the possibility of the turbine running

along with an extremely light load, which condition would cause more rapid valve wear.

Provision is made for varying the temperature range of the apparatus to suit conditions, and in general, control can be furnished for any desired range of temperature. Pressure heads may also be used and the turbine controlled to maintain a constant pressure instead of a constant temperature.

Valve Shuts Off Oil if Atomizing Pressure Falls

IN ORDER to cut off the oil supply to fuel oil burners should the atomizing air or steam pressure drop below the required minimum, an automatic shut-off valve has recently been developed. As long as the atomizing steam or air pressure is available, the valve is held wide



AFTER AUTOMATICALLY CLOSING, THE VALVE MUST BE RE-SET IN THE OPEN POSITION BY HAND

open. A failure of the pressure, however, causes the valve to close automatically and lock in the closed position so that even if the atomizing pressure were brought up to a satisfactory point, the valve would remain closed until an attendant would reset the trip-lock mechanism by means of the lever. Once the mechanism trips and closes the valve, it cannot be opened except by hand manipulation of the lever.

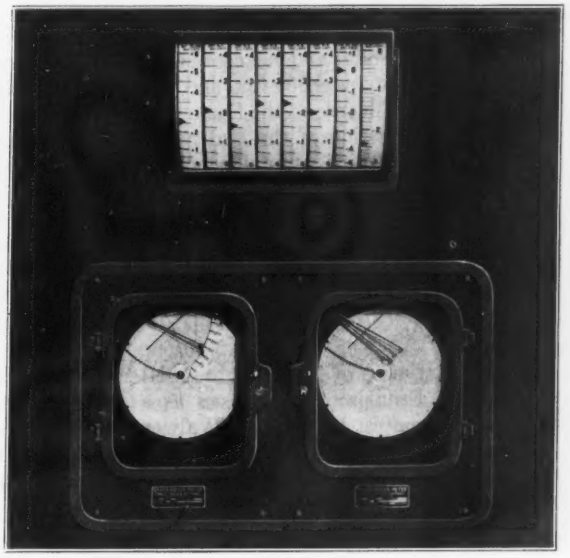
As shown in the accompanying illustration, the automatic shut-off valve consists essentially of a reverse-acting valve N on the bonnet M of which is mounted a two-arm spider E which supports a diaphragm chamber. The upper half of this diaphragm chamber is formed by the metal dome C and the lower half by the reinforced rubber diaphragm D against which a saucer rests, the latter being connected to the upper part of the trip mechanism H. The lower part of the trip mechanism is connected to the valve stem which is surrounded by the valve closing spring K.

This trip mechanism is set by means of the trip setting lever G and all parts are in the open position shown in the illustration. The steam (or air) pressure enters the diaphragm chamber through pressure connection A and holds the saucer against the pressure of spring B. If the pressure fails, the spring B will immediately raise the saucer and thus operate the trip mechanism. The operation of the trip mechanism enables the spring K to raise the valve disc Q instantly up against the valve seat P thus instantly closing the valve and shutting off the oil flow.

If, after the valve is shut, the steam (or air) pressure is brought up to its proper amount, the valve will not open until it has been reset by hand. The saucer will be forced down against the spring B, but this movement will have no effect on the position of the valve stem or of the valve disc and the valve will therefore remain closed. To reset, it is necessary to manipulate the hand lever G which brings the trip mechanism into its proper relation as an integral part of the valve stem. The required minimum pressure below which the valve closes can be adjusted by means of trip stud F.

Boiler Meters Brought Out in Flush Front Types

RECENT ideas in power plant design have led the Bailey Meter Co., of Cleveland, Ohio to bring out new types of metering equipment to meet the most exacting requirements. These flush front meters and gages



BOILER METERS WITH FLUSH TYPE MOUNTINGS

shown in the accompanying illustration are designed for panel board mountings and are so constructed that the meter casings and all connecting piping are behind the panels.

The double flush front meter shown near the bottom of the illustration was designed for a boiler equipped with an economizer. Steam flow and air flow are recorded on the left-hand chart while the temperature of the feed water entering and leaving the economizer as well as the temperature of the flue gases leaving the boiler and leaving the economizer are recorded on the right-hand chart. The eight pointer Multi-Pointer gage above this meter is suit-

able for installation on a boiler fired with a forced blast chain grate stoker. It indicates wind box pressure, five compartment pressures, fire box draft and uptake draft. The Multi-Pointer gage is also built in the flush front type.

Flush front meters of the double type as shown are also applicable for use on large double outlet boilers where it is necessary to measure the steam flowing through the two outlets, not only to obtain the total steam from the boiler, but also to determine whether or not the steam is equally divided between the two outlets and thereby assure the boiler operators that the non-return valves are operating properly.

News Notes

ON DEC. 18 the world's largest hydroelectric power unit was placed in commercial operation at Niagara Falls, before a delegation of prominent electric power men and Government officials in the new power plant of the Niagara Falls Power Co. on the American side of the Niagara River. The generating unit is a 65,000-kv.a., 107-r.p.m., 12,000-v., 25-cycle vertical waterwheel driven generator, driven by a 70,000-hp. hydraulic turbine. It is the first of two such units now being installed by the General Electric Co. and the William Cramp & Sons Ship & Engine Building Co., of Philadelphia. The station, when completed, will have a rated capacity of 454,000 hp. The unit just installed uses 3500 cu. ft. of water per sec. with an efficiency of at least 93 per cent.

APPLICATIONS involving an estimated installation of 21,500,000 hp. permits and licenses issued for an aggregate installation of 7,500,000 hp., and 2,400,000 hp. built or building under license of the Commission, is the record of 3 yr. administration of the Federal water power act, according to the third annual reports of the Federal Water Power Commission. In this period the Commission has dealt with applications involving six times as much horsepower, has issued permits and licenses involving three times as much horsepower and has twice as much horsepower built or building as the individual departments working independently in the preceding 20 yr.

F. R. ROBINSON, of New Brighton, N. Y., who is connected with Francisco & Jacobson as a designer, won the guessing contest held by the Walworth Manufacturing Co. at the Power Show. Mr. Robinson guessed 11,875 lb. as the weight of the Walworth exhibit, the correct weight being 11,904 lb.

RALPH E. GILMAN, special engineer in charge of turbo-generator engineering of the Westinghouse Electric & Manufacturing Co., died in the Methodist Hospital, Los, Angeles, Dec. 5. Mr. Gilman, on account of illness, had been granted a leave of absence from his duties in East Pittsburgh, Pa., to go to the coast in an effort to improve his health.

THE NEW POWER plant of the Great Northern Paper Company, at Anson, Me., has been completed and has been placed in operation. The new plant includes five 1500 hp. water turbines with direct connected generators, requiring 3000 cu. ft. of water per second to operate the turbines to capacity. Much excavating was done before solid foundations could be obtained for the dam in the Kennebec River but since then the construction has gone forward rapidly.

COMMENCING JAN. 1. the Middletown division of the Connecticut Power Co., which has been managed for several years past by Stone & Webster, of Boston, will be managed by the Hartford Electric Light Co., of Hartford, Conn. Announcement to this effect has been made at the Middletown plant. The Hartford Electric Light Company purchased the entire control of the Connecticut Power Co. about 3 yr. ago. The Connecticut Power Co. is capitalized for $2,250,000.

THE INGERSOLL-RAND CO. has secured from the New York Edison Co. an order for a 35,000-kw. surface condenser, to be installed under a 35,000-kw. General Electric Co. turbine at Waterside Station No. 1. It is of standard I-R external cooler design with single-pass water circuits. As auxiliaries are to be used two Cameron FV turbine-driven circulating pumps, two Cameron DV turbine-driven condensate pumps, two-stage I-R steam-jet vacuum pump equipment.

EDISON ELECTRIC ILLUMINATING CO., of Brockton, Mass., will enlarge the present East Bridgewater power station by installing two 588-hp. boilers and new oil burning equipment to provide for 6 boilers. The switching equipment at East Bridgewater will be rearranged and enlarged and a 13,200-v. transmission line will be built to Dupont Circle, Brockton where a two story substation will be erected and transformers and switching equipment installed. Contract has been awarded to Stone & Webster, Inc., Boston, Mass., for the work. The total estimated cost is $785,000.

CHANGES AND ENLARGEMENTS in power plants of New England textile mills include the following: Uxbridge Worsted Co., Uxbridge, Mass.; new power plant is under construction in which a new system of burning pulverized coal will be installed. Eagle Lake mills of the Jefferson Manufacturing Co., at Jefferson, Mass., have let contracts for a new power plant to the Fiske-Carter Construction Co., Worcester, Mass. Cole, Osgood & Kimball, of Boston, Mass., are engineers. The company plans on using hydro-electric power. Hockanum Mills Co. and the American Mills Co., of Rockville, Conn., will construct a large modern steel flume to increase the water flow for the hydroelectric and water wheel plants. The present flume which it will replace has been in use 35 yr. S. Slater & Sons, Inc., will install oil burning equipment in their power plant at the East Webster mills, at Webster, Mass., and are constructing a brick chimney 18 ft. in diameter and 175 ft. high to replace the present steel stack. Lockwood, Greene & Co., of Boston, are the engineers. The new hydroelectric plant of the Salmon Falls Manufacturing Co., at Salmon Falls, N. H., has been completed and operations started. The plant now consists of two 1500-hp. units and replaces the former water power units.

AMERICAN STEAM PUMP CO. of Battle Creek, Mich., has purchased the plant, assets and entire business of the Advance Pump & Compressor Co., of that city, negotiations having been completed on Nov. 21. The Advance Pump & Compressor Co. as a corporation has therefore dissolved and all business in the future will be carried on by and under the name of the American Steam Pump Co., and the pumps heretofore known in the field as "Advance" under the American ownership will be known as "American-Marsh."

On Dec. 11, the 25 and 60-cycle power systems of the New York Edison Co. and the United Electric Light & Power Co. were tied together at the Hell Gate station of the latter company. This tie-in was accomplished by means of a General Electric 35,000 kw. induction synchronous type frequency converter, establishing a record in frequency converter ties, representing a total of 727,000 kv.a. working in synchronism on the two systems. The induction unit is the largest induction motor in the world and has a continuous rating of 37,000 kv.a. The synchronous generator, rated 25,000 kv.a., is larger than any horizontal shaft salient pole generator previously constructed.

Theodore Maynz, who for the past four years has been test and results engineer for the Cleveland Electric Illuminating Co., has entered consulting work with headquarters at 3326 Kenmore Road, Cleveland. Previous to his connection with the Cleveland company, Mr. Maynz was with the Gulf Oil Corporation in charge of oil and steam engine power stations; with the Federal Light & Traction Co., Trinidad, Colo., in charge of construction and operations; with the Combustion Engineering Corporation on testing and construction and previous to that was with the Interborough Rapid Transit Co. He is a graduate of Harvard and took his engineering work at Columbia.

Ohio River Edison Co. has placed with the Westinghouse Electric & Manufacturing Co. an order amounting to approximately three-quarters of a million dollars for substation equipment to be installed in the new $10,000,000 steam power plant now under construction at Toronto, Ohio. The order includes seven 12,500-kv.a. transformers for stepping up power at the Toronto station from 13,200 to 132,000 v., and seven 12,500-kv.a. transformers for stepping down power at the Boardman substation from 125,000 to 66,000 v. The step-down transformers have three windings, the third of 6000-kv.a. capacity for synchronous condenser operation. In addition to the transformers, the order includes: one 15,000-kv.a., 3-phase, 60-cycle, 6600-v. synchronous condenser with direct connected exciter and miscellaneous equipment.

Books and Catalogs

In a folder entitled "The Story of the Navy," the Sugar Apparatus Mfg. Co., of Philadelphia, presents the steps which led up to the adoption by the navy of low pressure film evaporators.

Internal Combustion Engines, second edition, 1923, by Robert L. Streeter; 443 pages, 205 illustrations, 6 by 9 in., cloth; New York.

Any textbook dealing with present day practice is reliable only so long as changes are made in it to keep pace with the advance in the art with which the book deals. This is particularly true of a book on internal combustion engine practice which has made rapid strides in the past few years. The first edition of Internal Combustion Engines was brought out in 1915 and the second edition has been revised to bring it up to date. The book is written with the assumption that the reader has studied thermodynamics and mechanics although a review of thermodynamic principles which are essential to a clear understanding of the theory of internal combustion engines, is given. No radical changes have been made in the second edition and the book continues to be just what it started out to be; a sound text book for the student who is interested in theory, design and some idea of the method of operation of the internal combustion engine.

"Cutting the Cost of Producing Steam" furnishes the subject matter for bulletin No. 230 recently issued by the Detroit Stoker Co., of Detroit. In the discussion, it is shown how the Detroit single-retort underfeed stoker aids in the reduction of fuel costs. A cross-sectional view of the stoker shows its features and the details are then presented.

"Burning Waste Fuels" is the title of a bulletin now being distributed by the Sanford Riley Stoker Co., of Worcester, Mass. This bulletin takes up the special problems of burning hogged fuel, sawmill refuse, tan bark, sawdust, and other refuse. Test figures are presented and sketches give an idea of the special methods of feeding which are used.

"Oil Burning Under Steam Boilers" recently published by The Engineer Co., of New York City, discusses the merits of the flat-flame checker work type of burner, the mechanical burner using air register and the new system known as the SAR, which comprises a steam atomizing burner throwing a hollow cone spray used in connection with an air register.

De Laval Steam Turbine Co., Trenton, N. J., in its new catalog exhibits the marked development which has occurred in the improvement of centrifugal pumps, as well as in the direction of larger size and wider use. The rapid extension of the field of the centrifugal pump has been in large part due to improved efficiency, simplicity and ease of maintenance. The casings are split horizontally so that internal parts are at once accessible upon lifting the cover.

"Pulverized Coal for Boilers" is the subject of bulletin No. 900, published by the Fuller-Lehigh Co., of Fullerton, Pa. The introduction discusses the reasons behind the growth of pulverized coal as a fuel for boiler plants and then shows by means of curves how rapidly this type of equipment is being adopted. A large cross-sectional view of the coal preparation plant is shown, and the other part of the bulletin takes up in detail the various items of equipment which are used in such plants. Another bulletin issued by this same organization is "Fuller-Lehigh Equipment for Producing Pulverized Material" in which the screen type of pulverizer mill, the air separator type of mill, the impact unit pulverizer, crusher, feeders and burners, conveying and transport systems are briefly presented.

Following its established practice of the past several years, Link-Belt Co., of Chicago, has again issued a calendar for the ensuing year.

"Unity and Immunity for Fire Brick" is the title of a folder published by the Harbison-Walker Refractories Co., of Pittsburgh, Pa. This folder discusses the value of protecting fire brick with a bond of Thermolith.

"Shoot the Plugs" is the title of a folder issued by Mannion & Arthur Co., of Perth Amboy, N. J., in which the method of cleaning condenser tubes by blowing rubber plugs through them with compressed air is described.

In a new booklet entitled "Maphite," the Maphite Corporation of Chicago, Ill., has presented a discussion on refractories and the problems of building a furnace lining which will give service. One chapter gives instructions for the use of Maphite.

Information on high temperature heat insulation, is presented in bulletin No. 101 by the Philip Carey Co., of Cincinnati, O. Curves are shown which indicate the effect of high temperatures on different type of insulation both as to their heat transmission and strength.

Victor Jet Ash Conveyors are covered in a bulletin recently issued by the Victor Engineering Co. of Philadelphia. The discussion shows how the difficulties such as excessive consumption of steam, or compressed air, rapid wear of pipe, frequent clogging of pipe lines, objectionable dust and noise have been eliminated in the design of this type of system.

In describing its new line of centrifugal pumps, the M. T. Davidson Co., of New York City, has issued three bulletins, Nos. 101, 102 and 103. These bulletins have been combined with the regular catalog of Davidson steam pumps and bound in a loose leaf folder. The steam catalog incorporates tables and general data of interest to the operating and designing engineer.

De Laval flexible couplings are described in a folder issued by the De Laval Steam Turbine Co., of Trenton, N. J. This coupling, which has been developed for turbines or other motors geared or direct coupled to pumps, generators, and similar machinery, consists of two opposed flanges mounted on the driving and driven shafts respectively. One flange carries bolts or pins which enter holes bored in the opposing flange, but not coming into metallic contact with the latter, as the driving force is transmitted through steel lined molded rubber bushings slipped over the pins.

Insulation for temperatures varying from 200 to 1500 deg. F. is described in a new bulletin published by the Armstrong Cork & Insulation Co., of Pittsburgh, Pa. Fuel losses due to radiation is discussed and tables are presented showing the heat loss from unprotected piping for different pipe sizes and varying degrees of temperature difference between the pipe and the atmosphere. In addition to presenting the subject from an insulating efficiency standpoint, it is also taken up from the standpoint of qualities which insulation must possess in order to withstand high temperatures and moisture. A table is also presented giving recommended thicknesses of insulation for pipe sizes up to 30 in. in diameter and for temperatures up to 600 deg. F. Insulation for such equipment as vulcanizers, evaporators, cookers, oil refineries and miscellaneous industrial applications also make up a part of the bulletin.

Arc Welding and Cutting Equipment is taken up in catalog No. 23, which is now being distributed by the Torchweld Equipment Co., of Chicago. Apparatus described covers oxy-acetylene welding equipment for cutting, lead welding, brazing, soldering and decarbonizing.

"Hays Improved Gas Analyzers" is the subject of a new bulletin issued by the Jos. W. Hays Corp., of Michigan City, Ind. The reasons for flue gas analysis, the development of gas analyzers, and operating instructions are some of the general subjects covered. In addition, the Hays analyzer is described and illustrated.

In the new handbook of power apparatus standards, which the Electric Power Club of Cleveland has recently issued, a number of additional standards and practices have been incorporated. The basis of motor ratings has been changed and a few of the new standards which have been added are as follows: Oil Circuit Breaker Definitions, Step-Up Power Transformers, Storage Batteries, Switchboard Definitions, Synchronous Motors, Arc Welding Machines.

Pop Safety and Relief Valves are covered in catalog No. 1400, recently issued by the American Schaeffer & Budenberg Corp., of Brooklyn, N. Y. This includes a description of the new American Model J High Capacity pop safety valve, which is a new development of the company. This safety valve is particularly suited for water tube boiler service where saturated steam not exceeding 250 lb. pressure is encountered. The catalog also includes a capacity table on this new valve.

Westinghouse Underfeed Stokers of the new model design are covered in a bulletin which has been published by the Westinghouse Electric & Mfg. Co. of Pittsburgh. This stoker, which is of the inclined multiple retort type, has a number of interesting features of design and construction. Among these details are the secondary ram, the extension agitating grate, the extension side wall tuyeres, the double dumping grates and the ash discharging devices. Some detailed information is also presented on the design of the tuyeres and other such items.

William Ganschow, president of the William Ganschow Co., of Chicago, has edited a handbook on gears and speed transformers which has been incorporated as a part of catalog No. 100 recently issued by the Ganschow organization. Aside from the formulas and data pertinent to gears and speed transformers, it also contains information useful in the designing of machinery to which they may be applied. There are also tables showing strength and weight of materials. trigonometric functions, geometric formulas, decimal equivalents, wire and sheet metal gages and standard screw threads together with other miscellaneous information.

Three new bulletins have recently been issued by the American Brass Co. of Waterbury, Conn., which deal with the subjects of condenser tubes and brass pipe. The one on brass pipe for water service presents information on the effect of corrosion on various kinds of pipe and shows how brass pipe meets the requirements of this service. The bulletin on Anaconda condenser tubes discusses the specifications of tubes and goes into a discussion on the effect of annealing, grain, sizes and other points. "Anaconda Condenser Tubes in the Power Plant" is the third bulletin of this series.

Considerable information on conveying and elevator belting is presented in a new handbook which is now being distributed by the Goodyear Tire and Rubber Co., of Akron, O. Numerous problems are presented together with their solution, which shows the method of figuring the size of conveyor and elevator belts for varying conditions and layout.